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THE COMPOSITION AND CHARACTERISTICS OF SOYBEANS, SOYBEAN FLOUR, AND SOYBEAN BREAD [1]

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Introduction

Soybeans and soybean products constitute the chief source of protein food of hundreds of millions of people—Chinese, Japanese, Koreans, and Manchus. Soybeans play a much greater rôle in the nutrition of these people than does wheat in this country, or rye in Germany, Scandinavia, and the U. S. S. R., for, unlike the cereals, which are chiefly used in the preparation of baked products (mostly bread), soybeans are converted into numerous products which can be substituted, in a general way for such foods as cow's milk, cheese, eggs, and meat. For nearly fifty centuries the people of the Orient have subsisted on the products of the soybean, and hundreds of millions of these people have never even known the taste of cow's milk. While these people are essentially vegetarians, the protein fraction of their diet, supplied or supplemented largely from soybean products, is adequate and, according to Horvath (1931, 1931a), their diet is well-balanced. It is well known, furthermore, that the soybean-eaters of Northern China have greater stamina than the inhabitants of Southern China who subsist largely on rice (Anon. 1929). The soybean is a highly nutritional and adequate food.

Soybeans belong to the group of plants known as legumes, which includes peas, beans, cowpeas, and peanuts. Its botanical name is *Soya max* (Piper). There are many hundreds of varieties of soybeans, differing from one another by certain peculiarities, such as size, shape,

[1] Food Research Division Contribution No. 242.

color, and composition of seed, time of maturity, and many plant characteristics.

The soybean was introduced into Europe (Austria) in 1873, and a few years later Haberlandt (1878) published the results of extensive investigations regarding the optimum conditions for growing it, calling especial attention to its value for agricultural and food purposes.

Although the first description of soybeans dates back almost 5,000 years (Westl, 1926), and soybean products have been the main food of the Orientals for more than a hundred generations, it is only within the last decade that the use of soybean flour for food purposes in this country has been seriously considered.

Acreage, Production, and Price of Soybeans in the United States

Table I records the average acreage, production, and price per bushel of soybeans in each of the ten largest soybean producing States and in the entire United States in 1932 and 1933, based on data given in U. S. Department of Agriculture Yearbook, 1934.

TABLE I

Acreage, Production, and Unit Price of Soybeans

State	Average acreage 1932 and 1933 (1,000 acres)	Average production 1932 and 1933 (1,000 bu.)	Average price per bushel 1932 and 1933 (Dollars)
Illinois	302.5	5,325.0	0.540
Indiana	122.0	1,897.0	0.575
Missouri	110.5	1,315.0	0.720
N. Carolina	78.0	898.0	0.740
Iowa	52.5	915.5	0.585
Delaware	27.0	310.5	0.965
Ohio	23.0	362.0	0.660
Tennessee	17.5	127.0	0.975
Virginia	16.0	176.0	0.755
Kansas	11.0	82.0	0.795
United States	822.5	12,149.0	0.725

The farm price of soybeans in this country varies considerably; it averaged as high as $1.92 per bushel during the crop year 1929–30, and as low as $0.60 in 1931–32.

While the yield per acre averages about 15 bushels under favorable conditions, many localities produce as much as 35 bushels per acre. Besides almost 1,000,000 acres devoted to the production of the bean itself, more than 2,000,000 acres are used in growing soybeans for hay, forage, pasture, and silage. According to Burlison and Whalin (1932),

some 3,245,000 acres were sown to soybeans in 1929. Of the 1930 crop, 56% was for hay, 16% was grazed, and 28% harvested as beans, yielding about 13,300,000 bushels. Of this yield of beans, some 3,500,000 bushels were used for feed; 4,600,000 bushels were used for seed; and 4,800,000 bushels were crushed for oil. Only 400,000 bushels were ground, half of which was for feed and a like amount for food. The crushed soybeans supplied about 37,200,000 pounds of oil and 110,000 tons of meal. Of the oil produced, 5,800,000 pounds were used for food, of which 500,000 pounds were used for shortening and 750,000 pounds for oleo-margarine. Only 900 tons of cake meal were converted into flour for food purposes.

The production of soybeans in this country in 1933–34 totaled 11,177,000 bushels. During the same crop year Manchukuo produced 191,255,000 bushels, Chosen 24,093,000, and Dutch East Indies approximately 5,000,000. Japan's average production was about equal to our own. Fully 75% of the total supply comes from Manchukuo.

Table II records the production of soybeans in the United States for each of the five years, 1929 to 1934, as compared with soybean production in other countries.

TABLE II

SOYBEAN PRODUCTION IN SPECIFIED COUNTRIES[1] 1929–1933
(*1000 bushels*)

Crop year	United States	Manchukuo	Chosen	Japan	Dutch East Indies
1929–30	8,670	178,389	20,434	13,592	3,917
1930–31	12,217	193,564	22,989	15,531	4,693
1931–32	15,463	192,058	21,155	12,719	4,722
1932–33	13,121	156,817	22,578	—	5,471
1933–34	11,177	191,255	24,093	—	—

[1] U. S. D. A. Yearbook, 1934, page 557.

USES FOR SOYBEANS

Soybeans are used in a variety of ways and for many different kinds of products. Soybean flour is a valuable source of vegetable protein and may be used in connection with wheat flour in the production of various baked products, such as bread, cake, cookies, crackers, scones, and pie crust, as well as in macaroni, pretzels, doughnuts, etc. Soybean flour is also sometimes used in ice cream, ice cream cones, candies, puddings, and salad dressing; it has likewise found use as a sausage filler. In recent years because of its low starch content it has found a place as a diabetic food as well as in many proprietary foods. In the Oriental countries soybeans are used in the production of soybean milk

and curd, various soy sauces, fermented products, bean sprouts, and numerous other foods. Soybeans are also used in confectionery, soups, potted meats, food drinks, breakfast foods (puffed beans, flakes, and prepared meal), as salted roasted beans, and soybean butter, and as a substitute for coffee.

Chemical Composition of Soybeans

Soybean seed varies greatly not only in color and size but in composition. The variations in composition as developed by hundreds of analyses made by the Bureau of Chemistry, are given in Table III.

TABLE III

Chemical Composition of Soybeans

	Minimum	Maximum	Average
	%	%	%
Moisture	5.02	9.42	8.0
Ash	3.30	6.35	4.6
Fat	13.50	24.20	18.0
Fiber	2.84	6.27	3.5
Protein	29.60	50.30	40.0
Pentosan	3.77	5.45	4.4
Sugars	5.65	9.46	7.0
Starch-like substances by diastase	4.65	8.97	5.6
P_2O_5	1.50	2.18	1.7
K_2O	2.01	2.64	2.3
CaO	0.49	0.63	0.5
MgO	0.46	0.55	0.5
Weight per 1,000 seeds, *grams*	40	248	150

The composition of soybeans is dependent on the soil, on the climatic conditions under which they are grown, and also on the variety. The fat content may fall below 14% or may reach over 24%, while the protein, according to our analyses, may range from 30.0 to 50.0%. In general, soybeans with low fat content are high in protein; those high in fat are low in protein. This is, however, not always true for occasionally one encounters samples or varieties of soybeans which are relatively low in both fat and protein. For example, ten samples of soybeans examined by us had a fat content ranging from 13.97 to 15.88% (ave. 15.23%) and contained from 34.75 to 39.55% protein, the average being 37.73%. Climatic conditions are an important factor and should always be considered. It is now a well-recognized fact that soybeans of the same variety grown in different localities vary greatly in fat and protein, the two main constituents.

In Table IV are shown analyses of soybeans grown during the same

season in different localities. It is more than probable that with different climatic conditions prevailing during another season, a different percentage of fat or protein would have been found.

TABLE IV

FAT AND PROTEIN CONTENT OF SOYBEANS GROWN IN DIFFERENT LOCALITIES [1]

Locality	Number of samples	Percentage of fat			Percentage of protein		
		Minimum	Maximum	Average	Minimum	Maximum	Average
Raleigh, N. C.	32	16.02	22.95	19.90	30.81	41.50	37.34
Angleton, Tex	31	14.37	19.77	17.82	40.70	47.90	43.66
Athens, Ga.	33	15.93	24.23	21.64	29.56	38.75	34.10
Baton Rouge, La.	25	16.83	22.22	20.26	33.80	43.55	37.41
Beaumont, Tex.	32	14.00	22.20	15.33	37.00	47.60	43.45
Blacksburg, Va.	31	14.40	19.73	17.63	35.30	42.75	39.25
College Park, Md.	32	14.55	18.26	16.83	34.37	43.70	39.60
Clemson College, S. C.	33	16.02	24.68	22.30	29.80	38.56	32.44
Columbia, Mo.	32	16.70	21.52	19.18	34.20	41.75	36.83
Florence, S. C.	33	15.47	24.61	21.69	31.30	42.60	35.01
Fayetteville, Ark.	30	17.60	23.76	20.51	31.00	39.20	35.91
Gainesville, Fla.	37	15.22	22.96	19.72	32.45	44.05	37.03
Knoxville, Tenn.	30	14.65	21.56	19.24	32.30	43.25	37.92
Norfolk, Va.	32	15.62	24.36	20.48	34.30	39.60	37.19
Monetta, S. C.	28	15.07	24.73	20.66	31.25	43.70	35.75

[1] These soybeans were grown under the general direction of W. J. Morse of the Bureau of Plant Industry. For the most part the varieties grown in one locality were the same as those produced in the other localities.

Riede and Rewald (1933) state that climate is an important factor in influencing the composition of soybeans. They state that soybeans grown in Manchuria and in the United States are richer in fat and protein than those grown in Germany; that the application of phosphatic fertilizers affects favorably the fat and protein content; that the use of lime likewise increases the nitrogen and fat of the crop; but that nitrogen fertilizers increase only the protein of the bean and decrease the fat, whereas potash fertilizers increase the fat and decrease the protein.

The mineral constituents of the soybean. Soybeans contain 2 to 3 times as much ash as does wheat, 4 times as much potassium and sodium, 5 times as much calcium, 3 times as much magnesium, 2 times as much phosphorus, about the same amount of sulphur, but only one-third as much chlorine. As shown by Table V, soybeans are also richer than navy beans, lima beans, and cowpeas in most mineral constituents.

TABLE V

MINERAL CONTENT OF VARIOUS LEGUMES AND GRAINS
(*Air-dry Basis*)

	Percentage							
	Ash	K	Na	Ca	Mg	P	S	Cl
Soybeans [1]	5.06	1.913	0.343	0.210	0.223	0.592	0.406	0.024
Navy beans [1]	3.78	1.186	.074	.201	.176	.367	.192	.040
Cowpeas [1]	3.69	1.403	.162	.100	.208	.456	.240	.040
Peanuts [2]	2.27	0.654	.050	.071	.180	.399	.224	.056
Lima beans [2]	4.10	1.741	.249	.071	.188	.338	.161	.026
Peas [2]	2.90	0.903	.104	.084	.149	.400	.219	.035
Wheat	1.90	0.477	.039	.043	.136	.421	.202	.023
Corn	1.35	0.359	.032	.013	.113	.394	.155	.066
Rye [2]	1.70	0.453	.035	.055	.130	.385	.170	.025

[1] Ohio Agr. Expt. Sta. Bull. 255 (1913).
[2] Sherman—Chemistry of Food and Nutrition, 4th ed. (1932)—Table 61.

PROCESSES FOR THE REMOVAL OF THE BITTER TASTE OF SOYBEANS

Unfortunately, the varieties of soybeans produced most extensively in this country have an unpleasant beany taste. It is quite impossible to use them for food, either the beans themselves or as flour, until this "beany" taste has been removed. Not only does the flour from the untreated soybeans have an unpleasant taste, making it commercially undesirable as food, but the flour is apt to become rancid in a relatively short time.

One of the early processes patented in this country for removing the disagreeable taste from soybeans was that of Yamamoto (1919). This process consisted in steeping the cracked soybeans (free of hulls) in a solution of vinegar (1 to 2 parts of vinegar to 100 of water) at a temperature of 60° C. The solution was then decanted, and the beans were washed with water containing 140 to 200 g. sodium bicarbonate per 100 liters water. This second solution was decanted, and the beans were dried and ground. This early process has not, to our knowledge, been used to any appreciable extent commercially.

The first successful attempt to prepare a soybean flour which would be free from the disagreeable beany taste, which would remain fresh almost indefinitely (that is, not develop rancidity), and which would retain, practically unchanged, the original composition of the bean is described in the Berczeller patent (1924). This process consists in subjecting the cleaned soybeans to the action of saturated steam for 10 to 15 minutes. The beans are then dried, cracked in order to remove the hulls, and ground into flour. Such flour has a sweet, pleasant, nut-like taste (a characteristic of most flours obtained from soybeans which have been subjected to a special beany-taste removing treatment), and may be kept for many months without spoilage due to the development of rancidity. A later patent (1932) issued to this inventor consists in subjecting soybeans (dry or soaked) to steam distillation (see also Berczeller, 1933). In making soybean flour by this process in this country, the beans used, generally the yellow variety, are first treated to destroy insects and insect eggs. The beans are then cleaned or freed from impurities, washed to remove the dirt, and subjected to the patented process. The beans are then dried and passed through cutting machines and the hulls are removed by aspirators and bolting machines. The cut beans are then aerated with warm air and ground in a special air-cooled mill, the fine flour being bolted through a special bolting machine.

Numerous modifications of this process have in the meantime been evolved, but all have for their object the removal of the unpleasant beany taste and the preparation of a soybean flour which has good keeping qualities and is suitable for food purposes.

Among the patented processes may be mentioned the following: The Shellabarger (1932, 1933, 1933a) process consists in treating the cleaned soybeans with steam at 140° F. in a partial vacuum (24") for about 40 minutes, after which they are cooled and dried in an atmosphere of CO_2. They are then cracked, the hulls are removed, and the hull-free beans are ground into flour. Such flour has essentially the same composition as the hull-free soybean. If a flour of low oil content is desired, the hull-free beans are pressed to remove part of the oil and the oil cake is ground into flour. The flour thus prepared for bakers' use is said to have a much higher absorption capacity than has wheat flour.

The Baile (1927) process consists in soaking the cleaned soybeans for 12 hours or steaming them in order to facilitate the removal of the hulls. The hull-free beans are placed in hot peanut oil or other suitable oil until brown or brittle. Then, while still hot, the beans are ground.

The Gössel (1931, 1932) process consists in dipping the soybeans in oil at 95–100° C. for 5 minutes; centrifuging to remove the excess of oil and grinding into flour. The American (Gössel, 1933) patent advocates heating the soybeans with about 1% paraffin oil (100–110° C.) for 5 minutes. The excess oil is removed, the beans are cooled, the hulls are removed, and the beans are ground into flour. The oil treatment loosens the hulls.

Czadek (1927) heats the soybeans to a temperature just below the point where a colored product would result. Heating the soybeans in this manner yields a product free from the beany taste.

The Austrian patent (Goller and Winkler, 1932) recommends heating the soybeans at 65–75° C. or just below the temperature at which the protein would be biologically altered.

In later Goller and Winkler patents (1933, 1933a) the statement is made that the bitter principle, which is due to glucosides and galactosides, may be removed by dialysis under pressure or in vacuum at 65–80° C., the hull or skin of the bean acting as a semi-permeable membrane.

Cohn (1932) treats the soybeans with a solution of weak acid at 75° C. The beans are then dried and ground, and the flour is heated to 35° C. or more.

According to Strohal (1931) the beany taste of soybeans can be removed by cooking them for 10 to 30 minutes at 100° C. They are then dried and ground into flour.

Oberhard's procedure (1932) consists in steeping the beans in water until they are swollen; or steaming them for half an hour and then drying them at 60–65° C.; or soaking them in 5% formaldehyde solution for 24 hours and drying them at 60–65° C.; or boiling them for a long time in an open vessel.

Haas and Renner (1932) claim that treatment of soybean flour with the lower aldehydes of the aliphatic group, formaldehyde, for example, will remove the beany taste.

Heymann and Neufeld (1934) treat the beans with slightly acidulated water at a temperature not exceeding 75° C., after which the beans are dried and ground.

Kaltshewa (1933) removes the bitter principle of soybeans by washing them and soaking them in 5% solution of salt and soda for 30 hours at room temperature, the solution being renewed several times. The hulls are then removed and the beans cooked under slight pressure; the escaping steam carries with it the volatile odors. The slightly cooked beans are then pressed, and the press cake is dried in thin layers at 100° C. The dried mass is ground to a fine flour.

Tzirkovich (1932) describes a commercial method of converting soybeans into deodorized flour.

According to Horvath (1931, 1931a), the beany flavor is located in the peripheral layers of the bean cotyledon. Much of this flavor is removed on soaking or on germination.

Other methods in use for removing the bitter principle of soybeans are for the most part modifications of the patented and published processes just enumerated. Among these are the following processes:

1. Heating soybeans or soybean flour at 120–300° C. for varying lengths of time.
2. Subjecting soybeans to the action of steam at 70° C. in a partial vacuum.
3. Treating soybeans with alcohol and steam in a partial vacuum.
4. Heating the ground soybeans in a steam-jacketed kettle to 200° F. and sub-

jecting them to hydraulic pressure. The cake thus formed is ground and bolted. This is the old process used in preparing the press cake.

5. Treating the beans as described under 4. The cake is then ground and the flour is heated. This not only sterilizes the flour but affects its composition. (See No. 991, Table VII.)

6. Crushing the clean, ground, and heated soybeans by means of an Anderson expeller, whereby a temperature above 212° F. is generated. The press cake is then ground and bolted. This is the more modern method.

7. Treating the split or ground soybeans with a dilute sulfurous acid solution, drying, then extracting the oil by means of a solvent and preparing the flour from the fat-free residue. (See No. 864, Table VII.)

8. Heating the beans in steam-jacketed pans at approximately 215° F. The steam used in heating is drawn off by vacuum or by a fan. The beans are dried, cooled, and milled. The loss may be as high as 25%, including the hull and excess water. (See No. 977, Table VII.)

9. The beans are simply ground by means of a hammer mill. This produced raw soybean flour which for certain purposes must later be further treated. (See No. 971, Table VII.)

10. Beans are heated at a low temperature, ground, and then dextrinized. (See No. 972, Table VII.)

Composition of Component Parts of the Soybean

Soybeans consist of 6 to 8% of hull, 90 to 92% of cotyledons, and 1.5 to 2% of germ, according to Li Yu Ying and Grandvoinnet (1912), also Piper and Morse (1923). The composition of the various parts of the soybean is that shown in Table VI.

TABLE VI

Composition of the Component Parts of Soybeans

	Proportion of the seed	Moisture	Protein	Carbohydrates	Fat	Ash
	%	%	%	%	%	%
Cotyledons	90	10.57	41.33	14.60	20.75	4.38
Embryo	2	12.01	36.93	17.32	10.45	4.08
Seed coat	8	12.53	7.00	21.02	.60	3.83

Ohtomo (1929) found that the oil content of the cotyledons is about twice that of the embryo. In other words, more than 95% of the oil of the soybean is in the cotyledons. Most varieties of soybean have a very thin seed coat or hull. When the soybean is swollen, as the result of soaking in water, it weighs more than twice as much as the dry bean.

Extraction of Soybean Oil

There are soybean oil mills in at least 10 states of this country, the total annual crushing capacity being about 10,000,000 bushels. In general, 3 processes are used in obtaining the oil and oil cake—(*a*) by

hydraulic pressure, (*b*) by use of Anderson expeller and (*c*) by solvent extraction, a new process very popular in Europe but not used to any appreciable extent in this country, until recently.

The meal produced by hydraulic pressure or expellers is "more or less heated" (Anon., 1932), and has a toasted, somewhat nut-like flavor.

Oil Extraction from the Soybean

Yield of oil and meal from soybeans. In the process of obtaining oil by the usual English method, that is, by means of the hydraulic press, 1 short ton of beans (33⅓ bu. of 60 lb.) yields 250 pounds of oil and 1,600 pounds of meal. Owing to the removal of the hulls and incidental loss of flour, the yield of edible flour is somewhat less than the meal. Similar yields of meal are obtained by crushing the cake from the Anderson expeller. In this process the pressure may be as high as 15,000 pounds per square inch, and the temperature is often high enough to roast the product.

In such processes as the Berczeller, Shellabarger *et al.*, all of which grind the whole bean, the yield of edible flour is about 85%.

The Methods of Analysis of Soybean Flour

With the exception of urease, the various constituents (Table VII) were determined by the methods of the Association of Official Agricultural Chemists (1930). Urease was determined by the following method:

> Place 0.2 g. soybean flour in a test tube (25 × 150 mm.) containing 5 cc. of water. Shake, then add 5 cc. of a 3% aqueous solution of urea. Connect this test tube with a similar one containing 10 cc. of $N/10 H_2SO_4 + 1$ drop of methyl red indicator; place both tubes in a water bath held at 40° C. and for a period of 30 minutes, at a pressure of approximately 90 mm. of water, pass a current of washed air through the tube containing urea into the tube containing the H_2SO_4. At the end of that period disconnect the tubes and remove and titrate the excess of H_2SO_4 with N/10 NaOH.

Chemical Composition of Soybean Flours

Soybean flours vary considerably in composition and food value, depending not only on the composition of the soybeans but also on the method or process of manufacture. The composition of various soybean flours is given in Table VII, and the comparative composition of soybean flours made from the whole bean and from the press cake, and of solvent-extracted flour is shown in Table VIII. Table IX shows the composition of solvent-extracted soybean flour and of other legume flours (Annen, 1933).

TABLE VII

COMPOSITION OF SOYBEAN FLOURS

Lab. No.	Percentage of various constituents													Alkalinity[2]	Urease activity [3]
	Moisture	Ash	Fat [1]	Fiber	Protein (N×6.25)	Total protein soluble in			Water soluble carbohydrates		CaO	P_2O_5	Lecithin (Lipoid—P_2O_5×12)		
						5% K_2SO_4 solution	1% NaCl solution	70% alcohol solution	Before inversion	After inversion					
														Cc.	*Cc.*
Group 1 [4]															
717	8.50	4.85	19.95	5.35	36.25	36.0	57.9	3.0	1.07	7.57	0.25	1.62	2.06	21.6	10.0
717 A	7.96	5.00	20.81	3.28	37.99	38.6	59.6	3.3	0.47	7.71	0.29	1.64	1.75	20.5	9.8
721	8.19	4.58	19.93	4.16	35.00	44.1	48.0	3.5	1.20	9.87	0.23	1.40	2.02	22.6	7.4
721 A	7.79	4.82	21.11	2.89	37.25	42.7	47.5	4.3	0.63	9.62	0.22	1.36	1.74	21.7	7.3
Maximum	8.50	5.00	21.11	5.35	37.99	44.1	59.6	4.3	1.20	9.87	0.29	1.64	2.06	22.6	10.0
Minimum	7.79	4.58	19.93	2.89	35.00	36.0	47.5	3.0	.47	7.57	0.22	1.36	1.74	20.5	7.3
Average	8.11	4.81	20.45	3.92	36.62	40.3	53.3	3.5	0.84	8.69	0.25	1.51	1.89	21.6	8.6
Group 2 [5]															
971	10.41	4.21	17.61	4.01	42.56	50.5	21.6	4.1	0.67	8.92	0.25	1.24	1.22	18.0	6.0
875	7.04	4.84	23.26	1.67	40.81	26.8	21.0	3.3	0.35	9.55	0.31	1.74	0.17	29.4	4.1
977	7.32	5.18	20.08	2.36	39.50	26.7	20.2	2.7	0.27	8.43	0.36	1.47	1.27	24.9	4.0
987	5.61	4.78	22.04	1.83	40.31	22.1	19.4	2.3	0.35	10.13	0.29	1.24	1.34	24.4	3.8
904	7.31	4.91	23.50	2.07	35.25	25.4	23.2	3.5	0.56	10.18	0.21	1.35	0.25	24.0	3.6
878	6.04	4.99	23.05	1.82	40.00	27.3	27.1	3.0	0.73	9.75	0.30	1.26	1.62	29.4	3.5
873	5.55	4.65	23.93	2.26	34.44	24.8	17.9	4.0	2.00	10.15	0.23	1.23	0.99	23.9	3.2
998	7.43	4.26	18.57	4.33	41.63	25.8	20.5	3.0	0.25	9.20	0.35	0.93	1.31	23.3	3.0
900	8.35	4.81	22.05	1.50	41.87	36.4	28.7	2.4	0.08	9.78	0.30	1.25	1.37	25.4	2.9
983	6.10	4.62	22.68	1.50	41.31	23.1	25.3	2.3	0.28	9.77	0.30	1.09	1.56	26.5	2.2
970	7.25	4.60	22.15	1.72	41.00	20.5	29.3	2.0	0.24	9.58	0.29	1.13	1.30	25.4	2.2
1040	4.09	4.84	21.22	1.82	41.25	—	—	—	0.29	11.06	0.22	1.15	—	—	1.4
735	4.45	4.47	22.68	1.90	44.87	28.4	23.3	3.4	0.12	8.99	0.27	1.16	0.84	22.8	1.0
976	6.60	4.68	20.26	1.58	44.62	23.5	18.0	2.6	0.00	9.91	0.28	1.11	1.37	23.7	1.0
995	8.54	3.68	19.75	2.40	49.37	6.8	6.4	1.7	0.19	5.37	0.36	1.31	1.46	20.1	0.3
874	9.26	4.48	18.15	2.08	44.06	25.1	36.2	9.5	2.37	8.46	0.25	1.20	0.25	23.7	0.2
972	8.39	4.26	17.97	4.30	43.43	9.7	7.4	3.7	0.03	8.74	0.26	1.24	1.20	20.5	0.2
Maximum	10.41	5.18	23.93	4.33	49.37	50.5	36.2	9.5	2.37	11.06	0.36	1.47	1.62	29.4	6.0
Minimum	4.09	3.68	17.61	1.50	34.44	6.8	6.4	1.7	0.00	5.37	0.21	0.93	0.17	18.0	0.2
Average	7.04	4.60	21.11	2.30	41.55	25.2	21.6	3.3	0.52	9.29	0.28	1.21	1.10	24.1	2.5

TABLE VII—(*Continued*)

Lab. No.	Percentage of various constituents													Alkalinity[2]	Urease activity[3]
	Moisture	Ash	Fat[1]	Fiber	Protein (N ×6.25)	Total protein soluble in			Water soluble carbohydrates		CaO	P_2O_5	Lecithin (Lipoid—P_2O_5 ×12)		
						5% K_2SO_4 solution	1% NaCl solution	70% alcohol solution	Before inversion	After inversion					
														Cc.	*Cc.*
Group 3[6]															
913	6.58	5.84	10.97	2.29	46.25	53.2	39.1	2.7	0.44	10.56	0.34	1.53	1.44	31.8	3.5
912	6.29	5.97	10.72	2.13	46.99	50.5	38.8	2.8	0.32	11.25	0.37	1.63	2.02	28.8	2.0
Average	6.44	5.90	10.85	2.21	46.62	51.9	39.0	2.8	0.38	10.91	0.36	1.58	1.73	30.3	2.8
Group 4[7]															
902	8.64	5.95	6.18	3.26	47.37	55.4	37.2	2.8	0.55	11.26	0.28	1.40	1.19	30.7	5.2
990	9.22	5.47	6.47	3.07	47.43	51.6	35.2	2.2	0.71	12.44	0.32	1.32	1.20	27.9	5.1
901	8.67	6.03	8.11	2.10	48.56	52.9	37.1	3.2	0.56	11.19	0.31	1.38	0.86	32.9	4.6
903	8.32	5.94	6.44	3.73	47.87	50.6	30.0	3.8	0.89	10.56	0.30	1.56	0.76	34.1	4.6
989	9.07	5.46	8.00	1.96	48.87	56.4	33.0	2.6	0.27	11.79	0.32	1.38	1.14	32.4	4.5
908	5.60	5.62	7.87	2.17	48.62	24.9	—	2.5	0.19	11.86	0.36	1.43	1.46	29.9	1.8
991	7.75	5.57	6.64	3.24	47.12	32.0	24.7	2.4	0.27	11.83	0.32	1.36	1.38	29.2	1.7
879	7.26	5.88	8.15	2.18	47.49	26.1	23.0	2.9	0.21	11.10	0.34	1.49	1.77	27.9	1.4
988	6.84	5.59	7.72	2.78	48.05	17.0	18.3	2.1	0.35	11.79	0.35	1.37	1.56	29.2	1.1
992	9.07	5.96	8.88	2.60	43.81	30.6	29.8	3.7	0.63	11.42	0.56	1.29	1.58	31.4	1.0
984	6.46	5.86	7.20	2.08	49.76	19.3	17.7	2.6	0.00	11.44	0.35	1.30	1.25	29.9	0.9
880	6.36	5.92	6.50	5.05	46.31	35.2	27.1	2.8	0.33	11.25	0.33	1.47	1.37	30.4	0.9
876	7.07	5.53	7.81	2.35	49.12	19.7	12.2	3.5	1.04	11.60	0.36	1.35	1.41	29.2	0.2
881	7.50	5.78	6.21	5.87	43.93	17.5	18.6	2.5	0.28	10.65	0.41	1.54	1.28	28.3	0.2
Maximum	9.22	6.03	8.88	5.87	49.76	56.4	37.2	3.8	1.04	12.44	0.56	1.56	1.77	34.1	5.2
Minimum	5.60	5.46	6.18	1.96	43.81	17.0	12.2	2.1	0.00	10.56	0.28	1.29	0.76	27.9	0.2
Average	7.70	5.75	7.30	3.03	47.45	35.0	26.5	2.8	0.45	11.44	0.35	1.40	1.30	30.2	2.4
Group 5[8]															
864	7.73	2.66	1.58	3.04	68.74	8.9	7.0	2.4	0.03	0.06	0.61	1.03	0.66	8.8	0.9

[1] Includes lipoids.
[2] Cc. N. acid required to neutralize ash from 100 g. flour.
[3] Cc. N/10 ammonia.
[4] Group 1 represents soybean meal prepared by the authors, 717 and 721 from whole beans; 717 A and 721 A. hulls removed.
[5] Group 2 represents samples of commercial soybean flours having high fat content.
[6] Group 3 represents samples of commercial soybean flours from press cake having medium fat content.
[7] Group 4 represents samples of commercial soybean flours having low fat content.
[8] Group 5 is a commercial sample of solvent-extracted soybean flour.

TABLE VIII

COMPOSITION OF HIGH FAT, PRESS CAKE, AND SOLVENT-EXTRACTED SOYBEAN FLOURS

	High fat flours (17 samples)			Press cake flours (14 samples)			Solvent-extracted flour (1 sample)
	Minimum	Maximum	Average	Minimum	Maximum	Average	
	%	%	%	%	%	%	%
Moisture	4.09	10.41	7.04	5.60	9.22	7.70	7.73
Ash	3.68	5.18	4.60	5.46	6.03	5.75	2.66
Fat	17.61	23.93	21.11	6.18	8.88	7.30	1.58
Fiber	1.50	4.33	2.30	1.96	5.87	3.03	3.04
Protein	34.44	49.37	41.55	43.81	49.76	47.45	68.74
5% K_2SO_4 soluble N (% of total N)	6.80	50.50	25.20	17.00	56.40	35.00	8.90
1% NaCl soluble N (% of total N)	6.40	36.20	21.60	12.20	37.20	26.50	7.00
70% alcohol soluble N (% of total N)	1.70	9.50	3.34	2.10	3.80	2.80	2.40
Reducing sugar before inversion	0.00	2.37	0.52	0.00	1.04	0.45	0.03
Reducing sugar after inversion	5.37	11.06	9.29	10.56	12.44	11.44	0.06
CaO	0.21	0.36	0.28	0.28	0.56	0.35	.61
P_2O_5	0.93	1.47	1.21	1.29	1.56	1.40	1.03
Lecithin	.17	1.62	1.10	0.76	1.77	1.30	.66
Alkalinity [1]	18.00	29.40	24.10	27.90	34.10	30.20	8.80
Urease activity [2]	0.20	6.00	2.50	0.20	5.20	2.40	0.90

[1] Cc. of N acid per 100 g. sample.
[2] Cc. N/10 ammonia.

Soybean flour output in the United States. According to the Oil Miller and Cotton Ginner (Anon., 1932), in 1931 some 125,000 tons of soybean meal were produced, with an average protein content of 42%. The price was as low as $15 per ton.

TABLE IX

COMPOSITION OF SOLVENT-EXTRACTED SOYBEAN FLOUR AND OF OTHER LEGUME-FLOURS

	Moisture	Protein	Fat	Fiber	Ash
	%	%	%	%	%
Solvent-extracted soybean flour	8.05	52.13	1.18	2.97	5.94
Bean flour	9.97	22.84	2.97	1.81	3.23
Pea flour	10.67	24.93	1.99	1.41	2.74
Lentil flour	9.85	26.14	1.92	2.12	2.50

The present capacity of crushers is sufficient to produce enough soybean flour to supply the bakers on the basis of an addition of 4% of soybean flour to wheat flour for bread making purposes alone.

Soybean flour contains more than 40% protein. The protein actually soluble in pepsin-HCl is approximately 88% of the total (Stokes and Wright, 1929).

Soybean flours, either high or low in fat, contain in general less than 1% of reducing sugars and about 9% to 11% of sugar after inversion. As a rule, the fiber content of high-fat soybean flour is about 2%, although three of our commercial flours contained from 4.01% to 4.33%. These flours had not been bolted to free them of hulls. Likewise 2 of the 14 commercial samples of press cake flours average about twice as high in fiber as did the other 12 samples, indicating that likewise these 2 samples had not been bolted.

Soybean flours prepared according to the Berczeller process, or similar processes, have essentially the same composition as hull-free soybeans themselves.

Flour made from the press cake is naturally lower in fat and correspondingly higher in proteins and other constituents. These flours are also generally free from hulls or skins. The solvent-extracted flour, having first undergone a treatment with a dilute SO_2 solution, is not only low in fat but also in soluble minerals and soluble carbohydrates. This accounts for the exceedingly high protein content.

It has been noted that soybean flours which have been subjected to a more or less severe heat treatment are low in urease. Flours of this kind, which we have examined, have relatively little diastatic activity. Hence the urease content may be regarded as an indication of the proteolytic and diastatic activity. On the other hand, soybean flours which have not been heated so severely have, as a rule, a high diastase content. A small amount of such flour added to gelatinized starch results in the immediate production of considerable sugar. This is a simple method of determining whether a soybean flour has been subjected to severe heat treatment.

Soybean flour properly prepared, that is, one that has not been subjected to too great heat or to heat for too long a time, is believed to retain practically the full food value of the original bean, especially as regards the nature of its proteins, the solubility of its carbohydrates, and the presence of an appreciable amount of lecithin and of the essential vitamins and minerals. The wide variations in the percentage of soluble protein (NaCl-soluble, K_2SO_4-soluble, and alcohol-soluble) are no doubt due to the differences in heat treatment to which the beans were subjected during the process of removing the unpleasant taste, or as the result of special heat treatment of the flour.

The flours here reported are all commercial products, and information is lacking regarding the kind of soybeans used in the manufacture of each sample or where they were grown or the conditions of harvest-

ing, storing, etc., and in some cases no information is available regarding the process of manufacturing the flour. It is quite possible that in the process of manufacture some of these flours were heated more than others, thus rendering a portion of the proteins insoluble, for according to statements from the manufacturers, sample 972 was prepared from the roasted bean, and sample 995 from beans that had been dipped in hot oil. Both of these flours are especially low in K_2SO_4-soluble protein, and in NaCl-soluble protein. They are also low in urease.

Minerals of soybean flour. Although in the preparation of soybean flour the hull or skin of the soybean is generally removed, when compared with other natural and prepared foods soybean flour is rich in minerals (see Table X).

TABLE X

MINERAL CONTENT OF SELECTED FOODS

	Ash	Potassium	Sodium	Calcium	Magnesium	Phosphorus	Sulphur	Chlorine
	%	%	%	%	%	%	%	%
Rolled oats [1]	1.90	0.344	0.062	0.069	0.110	0.392	0.202	0.069
Rice [1]	0.40	0.070	.025	.009	.033	0.096	.117	.054
Milk [1]	0.74	0.143	.051	.120	.012	0.093	.034	.106
White bread [1]	1.10 [4]	0.108	.394 [4]	.027	.023	0.093	.105	.607 [4]
Eggs [1]	1.00	0.140	.143	.067	.011	0.180	.195	.106
Macaroni [1]	0.60	0.130	.008	.022	.037	0.144	.172	.073
Tomatoes [1]	0.50	0.275	.010	.011	.010	0.026	.014	.034
Radishes [1]	1.00	0.218	.069	.021	.012	0.029	.041	.054
Bananas [1]	0.80	0.401	.034	.009	.028	0.031	.010	.125
Soybean flour	5.70	1.860	.230 [5]	.300	.380	0.700	.365	.071
Wheat flour [2]	0.45	0.168	.003	.016	.029	0.113	.165	.051
Wheat germ	5.15	0.306	.754	.083	.353	1.112	.333	.071
Wheat bran	6.06	1.320	.201	.125	.531	1.110	.267	.090
Rice polish [3]	7.13	1.137	.110	.027	.659	1.407	.168	.134
Potatoes [1]	0.83	0.429	.021	.014	.028	0.058	.030	.038

[1] Sherman—Chemistry of Food and Nutrition, Ed. 4 (1932).
[2] B. Sullivan—Cereal Chem. 10: 505 (1933).
[3] Ohio Agr. Expt. Sta. Bull. 255 (1913).
[4] Includes salt.
[5] Commercial analysis.

According to Malkomesius and Schramm (1930), ground hull-free soybeans contain 6.3% of ash, and of this constituent 11.9% is hydrochloric acid insoluble, 8.0% is lime; 3.5% magnesia; 36.9% potash; 10.8% soda; 24.5% phosphorus pentoxide; 3.2% sulphur trioxide; and 1.1% chlorine. There is a trace of iron. This statement of composition agrees in general with the views of Osborne and Mendel (1917), who, however, claim that soybeans are relatively poor in calcium and chlorine. An examination of the tabulated data clearly indicates that soybean flour is rich in calcium. Organic phosphorus is also present in

a notable amount. Soybean flour contains such a large proportion of potassium, sodium, and magnesium that the ash of this food is physiologically alkaline.

Deschamp (1911) states that soybeans are rich not only in oil, protein, and phosphates, but also in potash and lime.

Carbohydrates of soybean flour. The soluble carbohydrates of soybean flour vary considerably in amount, especially among the whole bean flours. Very uniform results are noted in the flours made from the press cake. About 10% of sugars (after inversion) are present in these products. Of the total sugar, approximately three-fourths is sucrose and one-fourth raffinose. There is only about 1.5% reducing sugars. Probably no more thorough study has been made of the carbohydrates of the soybean than that of Street and Bailey (1915). According to these authors less than 2% of the nitrogen-free extract was in the form of starch. Sugar was present to the extent of 14% of the total carbohydrates, dextrin 10%, pentosans 16%, galactans 16%, cellulose 10%, organic acids, wax, color, etc., 32%.

The results of their determination, expressed in percentages of the whole meal, are as follows: Sucrose, 3.31; invert sugar, 0.07; raffinose, 1.13; starch, 0.50; dextrin, 3.14; pentosans, 4.94; galactans, 4.86 (less 0.24 due to raffinose); cellulose, 3.29; organic acids, as citric 1.44; waxes, color, etc., undetermined, 8.64; total, 31.08.

According to Johns and Finks (1921), the carbohydrates as well as the proteins and fats of soybeans are efficiently utilized. Because of their low starch content, soybeans are used as diabetic foods.

Quality of the protein in soybean flour. Not only is soybean flour extremely rich in protein, but this protein has especially high nutritional qualities (Osborne and Mendel, 1917). The chief protein of the soybean is glycinin, a globulin which contains all the amino acids essential for body-growth (Table XI).

The nutritive value of soybean and peanut proteins is shown by Shiba and Koyama (1923).

According to Simon (1933), the soybean protein forms very little uric acid in the body, and hence behaves more or less like casein.

Vitamins in soybean flour. Soybeans are an excellent source of vitamin A, a good source of B and G, and when germinated contain vitamin C. They are also a source of vitamin D (Horvath, 1935).

According to Westl (1928), vitamins A and B of soybeans are not impaired in preparing flour from the whole beans with only light heat treatment. On the other hand, solvent-extracted soybean flour is relatively free of vitamins A and D. These vitamins are found in the oil instead of in the flour. As refined foods are for the most part deficient

in vitamins and as much of the food consumed by the white race is of that character, the more common use of soybean flour and other soybean products would tend to supplement our vitamin-inadequate foods. Es-

TABLE XI

COMPOSITION OF THE PRINCIPAL PROTEIN OF GRAINS AND OTHER SEEDS [1]

	Glycine	Alanine	Valine	Leucine	Proline	Phenyl alanine	Tyrosine	Serine	Cystine	Aspartic acid	Glutamic acid	Arginine	Histidine	Lysine	Tryptophane	Hydroxy glutamic acid
Barley, hordein	0.0	1.4	1.4	7.0	13.7	5.5	2.4	0.1	1.50	1.3	43.2	3.20	1.30	1.0	1.0	
Buckwheat, globulin									2.50			12.97	0.59	7.9	2.1	
Maize, zein	0.0	9.8	1.9	25.0	9.0	7.6	5.9	1.0	0.80	1.8	31.3	1.80	0.80	0.0	0.2	2.5
glutelin	0.3			6.2	5.0	1.8	3.8			0.7	12.7	7.10	3.00	3.0		
Einkorn, prolamine									1.61			3.73	3.11	2.0		
Emmer, prolamine									2.36			4.46	1.72	2.7		
Oats, mixed protein	1.0	2.5	1.8	15.0	5.4	3.2	1.5			4.0	18.4					
glutelin									3.00			8.30	2.30	5.0		
gliadin									3.50			4.20	1.30	0.9	0.0	
Rice, globuin							5.6		2.10			7.80	2.40	7.1	2.7	
gutelin		3.7		14.3	3.3	2.0	5.3		1.10	0.4	14.5	9.10	3.30	4.3	2.5	
Rye, gliadin	0.1	1.3		6.3	9.8	2.7	1.2	0.1	2.60	0.3	33 8	2.20	0.40	0.4	0.7	
glutelin									2.60			7.10	2.13	5.4		
Wheat, glutin	0.4	0.3		4.1	4.0	1.0	1.9			0.7	24.0	4.40	1.20	2.2		
gliadin	0.0	2.0	3.3	6.6	13.0	2.3	3.1	0.1	1.90	0.8	43.7	2.90	1.50	0.6	1.1	2.4
glutenin	0.9	4.6	0.2	5.9	4.2	2.0	4.2	0.7	1.60	2.0	25.7	4.70	1.80	1.9	1.7	1.8
leucosin	0.9	4.4	0.2	11.3	3.2	3.8	3.3			3.3	6.7	5.90	2.80	2.7		
Wheat bran, globulin							3.7		1.50			14.10	2.80	11.4	2.8	
prolamine							3.4		2.30			4.40	0.80	2.4	1.4	
albumin							4.2		3.30			10.00	2.60	4.5	4.8	
Cowpea, globulin	0.0	1.0	0.3	7.8	5.2	5.3	2.3		0.50	4.0	16.9	7.20	3.10	4.3	1.6	
Soybean, glycinin	1.0		0.7	8.5	3.8	3.9	1.9		1.10	9.4	19.5	8.10	1.40	9.1	1.7	5.5
Navy bean, phaseolin	0.6	1.8	1.0	9.7	2.8	3.3	2.2	0.4	0.60	5.3	14.6	6.10	2.60	4.6	0.9	
Lima bean, a-globulin									1.60			5.70	3.70	7.8	1.9	
b-globulin									0.10			5.10	2.60	8.5	2.2	
albumin									1.10			5.70	2.50	6.0	1.4	
velvet bean, stizolobin	1.7	2.4	2.9	9.0	4.0	3.1	6.2	0.7	1.50	9.2	14.6	7.10	2.30	8.5	1.4	2.8
Pea, legumin	0.4	2.1		8.0	3.2	3.7	1.5	0.5	0.80	5.3	17.0	11.70	1.70	5.0	1.8	
legumelin	0.5	0.9	0.7	9.6	4.0	4.8	1.6			4.1	13.0	5.40	2.30	3.0		
vicilin	0.0	0.5	0.1	9.4	4.1	3.8	2.4		0.60	5.3	21.3	8.90	2.20	5.4	0.1	
Flaxseed, globulin	+	1.1	12.7	4.0	2.9	4.2	0.7		1.10	1.7	11.6	6.10	1.70	1.2	4.0	
Spelt, prolamine									1.40			3.50	2.80	2.7		

[1] Prepared by Dr. D. Breese Jones, Protein and Nutrition Division, Bureau of Chemistry and Soils.

pecially among the poorer classes should the vitamin-G-containing soybean flour find favor.

The foods listed in Table XII are relatively low in mineral content and in vitamins, yet they furnish more than 70% of the average American caloric requirements of 3,000 calories per capita per day. Recently Sherman (1934) said " I think it is well to provide at least half of the needed calories in the form of protective foods." These include fruits, green vegetables, eggs, and dairy products.

Soybeans and soybean flour may properly be considered as having protective food qualities because they are rich in minerals, rich in high quality protein, rich in fat and rich in vitamins, and hence serious thought should be given to their inclusion in the American diet.

Lecithin and fats in soybean flour. As was seen from Table VII,

soybean flour made from the whole beans usually contain from 1.0% to 1.5% of lecithin. One pound of soybean flour contains, therefore as much lecithin as 4 to 6 eggs (Beythien, 1914). When made from the

TABLE XII

THE CONSUMPTION AND THE MINERAL AND VITAMIN CONTENT OF SELECTED FOODS

Food	Yearly consumption in U. S. (1931) [1]	Per capita consumption 1931	Calories Per pound	Minerals	Vitamin potency [2]
	million pounds	*pounds*		%	
Refined sugar	12,017	98.5	1,860	—	None
Corn-starch	158	1.3	1,670	—	B_2 = +
Polished rice	719	5.9	1,630	0.4	None
White flour	20,825	170.7	1,620	.5	B_1 = + [3]
Corn-sirup	707	5.8	1,400	—	None
Corn-sugar	780	6.4	1,860	—	None
Candy	1,439	11.8	1,780	.5	None [4]
Hominy and grits	341	2.8 [5]	1,650	.5	A = +
Rye flour	292	2.4	1,660	1.5	B_1 = ± [3]
Corn-meal	2,598	21.3	1,730	1.0	B_1 = ± [3]
Corn breakfast food	378	3.1	1,620	.5	B_1 = ± [3]
Macaroni and water noodles	451	3.7	1,620	.6	B_1 = ± [3]
Corn and cottonseed oil	1,403	11.5	4,000	—	A = − to + D = − to + E = ± to +
Poultry	2,940	24.1 [6]	750	1.0	B_1 = + C = +
Beef; veal	6,893	56.5	1,000	1.0	B_2 = + E = +
Mutton and lamb	866	7.1	1,200	1.0	B_1 = + B_2 = +
Lard and lard substitutes	2,720	22.3 [7]	4,000	.1	A = ± B_2 = ±

[1] U. S. Dept. Commerce, Domestic Commerce Ser. 38, 1930, and Suppl. (mimeo) 1933.
[2] Chiefly from Browning's "The Vitamins."
[3] From the Protein and Nutrition Div., Bur. Chem. and Soils. + = fairly rich; ± = some present; — = absent.
[4] Refers to pure sugar candy only.
[5] 1919.
[6] 1927–31 average.
[7] 1922–26 average.

press cake, soybean flour contains a slightly larger proportion of lecithin. The presence of lecithin in soybeans may have some special physiological value because this phospholipoid is a constituent of all the vital organs of the body as well as of the nervous tissue. Occasionally the lecithin content of soybean flour falls to an unexplainably low point. As has already been pointed out, it is quite possible that the beans grown in certain parts of the country under peculiar soil conditions, and possibly harvested under adverse conditions, may themselves be deficient

in this valuable constituent, and it is not at all improbable that certain varieties may be more deficient than are others. Riede and Rewald (1933), however, found no appreciable difference in protein, fat, or lecithin in the beans of different colors, though the yellow bean is usually the richest in lecithin.

The lecithin P_2O_5 or phospholipoid makes up about 10% of the total phosphoric acid. In other words the phosphoric acid of soybean flours is mostly in the form of soluble phosphates. Egg yolk was the chief commercial source of lecithin until it was supplanted by soybean oil obtained in the solvent process. In the ordinary process of making soybean flour, either by the steam-treatment process or by the hydraulic process, the lecithin is for the most part left in the flour.

According to Horvath (1933), the use of lecithin in baking permits a more even distribution of the fat and improves the shortening effect. Ziegelmayer (1930) is of the opinion that the use of lecithin in bread making delays staling.

Not only does the fat of soybean flour contain lecithin and phosphoric acid (important constituents of wheat germ and egg yolk), but also considerable amounts of linolic and linolenic acids as constituents of the cell lipoid (Horvath 1931).

Soybean Flour and the Diet

Cost of protein and fat in soybean flour. From the data recorded in Table XIII it is apparent that the soybean is the richest in protein of all known foods except dried egg white. Even such concentrated animal foods as dried beef and cheese contain less protein than the average soybeans. Soybeans are also exceedingly rich in fat, although in this respect they are surpassed by other foods of vegetable origin such as the various nuts, chocolate, cocoa, olives, and peanuts, and by numerous cuts of meats, by certain animal products such as lard, oleomargarine, butter, and cheese, and by mackerel, young goose, and egg yolk.

The most expensive food constituents are minerals, vitamins, proteins, and fats. Soybean flour is rich in all these food constituents and yet relatively cheap. The moderate cost of soybean flour (5 to 6 cents per pound) makes it possible for people of small incomes to obtain the maximum of these essential nutritional constituents required by the body which in the form of other foods might be beyond their reach. According to Parsons (1927), the human body requires daily about 30 g. of biologically adequate protein; Chittenden (1907) had previously recommended 60 g. per day. At 6 cents per pound of soybean flour, the 60 g. of protein would cost about 2 cents or considerably less than the same amount in the form of any other food. Of the foods listed in

Table XIV, soybean flour is the cheapest source of protein and is exceeded only by lard, butter, peanuts, and ham as a cheap source of fat.

Cost of minerals in soybean flour. Soybeans are a cheap source of the minerals required by the body. To obtain 100 g. of minerals in the

TABLE XIII

COMPOSITION OF SELECTED FOODSTUFFS[1]

Food	Water	Ash	Fat	Fiber	Protein	Nitrogen free extract	Calories per 100 g.
	%	%	%	%	%	%	
Soybean flour (high fat)	7.4	4.7	21.5[2]	2.7	40.3	24.0	464
Soybean flour (low fat)	7.8	5.7	7.3[2]	3.0	47.6	28.6	380
White flour	11.4	0.5	1.2	0.2	11.5	75.3	367
White rye flour	9.6	0.7	0.9	0.5	9.4	78.9	370
Dark rye flour	9.5	2.0	1.8	1.9	15.8	69.0	364
Unbolted corn-meal	11.6	1.3	4.7	1.7	8.4	72.3	375
Oatmeal	7.3	1.9	7.2	0.9	16.1	66.6	406
Rice	12.3	0.4	0.3	0.2	8.0	78.8	359
Macaroni	10.3	0.6	1.3	0.2	12.0	74.4	366
White bread	37.0	0.3	2.0	0.2	9.2	50.1	262
Bean flour	10.0	3.2	3.0	1.8	22.8	59.2	364
Pea flour	10.7	2.7	2.0	1.4	24.9	58.3	360
Lentil flour	9.9	2.5	1.9	2.1	26.1	57.5	360
Dried beans	12.6	3.5	1.8	4.4	22.5	55.2	335
Dried peas	9.5	2.9	1.0	4.5	24.6	57.5	346
Potatoes	78.3	1.0	0.1	0.4	2.2	18.0	84
Spinach	92.3	2.1	0.3	0.9	2.1	2.3	21
Cabbage	91.5	1.0	0.3	1.1	1.6	4.5	28
Tomatoes	94.3	0.5	0.4	0.6	0.9	3.3	21
Bananas	75.3	0.8	0.6	1.0	1.3	21.0	97
Oranges	86.9	0.5	0.2	—	0.8	11.6	53
Apples	84.6	0.3	0.5	1.2	0.4	13.0	60
Sugar	—	—	—	—	—	100.0	410
Eggs	73.7	1.0	0.5	—	14.8	—	158
Milk	87.0	0.7	4.0	—	3.3	5.0	71
Cheese	31.6	3.4	35.9	—	28.8	0.3	453
Butter	11.0	3.0	85.0	—	1.0	—	795
Lard	—	—	100.0	—	—	—	930
Smoked ham	39.8	4.7	38.8	—	16.7	—	429
Veal cutlets	70.7	1.1	7.7	—	20.3	—	155
Leg of lamb	58.6	1.0	22.6	—	18.6	—	286
Round steak	67.8	1.1	10.6	—	20.5	—	184
Peanuts (shelled)	9.2	2.0	38.6	2.5	25.8	21.9	564
Pecans (shelled)	3.0	1.5	71.2	—	11.0	13.3	761
Walnuts (shelled)	2.5	1.7	64.4	1.4	18.4	11.6	727
Almonds (shelled)	4.8	2.0	54.9	2.0	21.0	15.3	668

[1] Compiled from various sources, chiefly from Office of Experiment Stations Bulletin No. 28, U. S. Department of Agriculture: The Chemical Composition of American Food Materials.
[2] Includes lipoids.

form of soybean flour costs about 28 cents. No other food shown in Table XIV is such an economical source of minerals. Further, the ash of soybean flour is very alkaline. While soybean flour is 4 to 10 times as rich in minerals as these other foods given in Table XIV, it is

TABLE XIV

RETAIL COST OF FOODS AND THEIR COMPONENTS[1]

Food	Cost of food			Cost of 100 grams					Obtainable for 10 cents						
	Per pound	Per 100 g.	Per 100 calories	Ash	Calcium	Fat	Protein	Nitrogen free extract	Weight	Energy value	Ash	Calcium	Fat	Protein	Nitrogen free extract
	Cents	*Cents*	*Cents*	*Cents*	*Dollars*	*Cents*	*Cents*	*Cents*	*Grams*	*Calories*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
Soybean flour (high fat)	6.0	1.32	0.28	28	4.40	6	3	5.5	756	3515	35.4	2.270	166.7	333.3	180
Soybean flour (low fat)	5.0	1.10	0.29	19	3.70	15	2	3.9	907	3454	52.6	2.700	66.6	500.0	256
White flour	5.0	1.10	0.30	244	68.80	91	10	1.4	907	3364	4.1	0.145	11.0	100.0	714
Unbolted cornmeal	4.0	.88	0.23	70	48.80	19	11	1.2	1134	4262	14.3	0.205	52.6	91.0	833
Oatmeal	6.0	1.32	0.33	69	19.10	19	8	2.0	756	3076	14.5	0.525	52.6	125.0	500
Rice	6.0	1.32	0.37	325	146.50	432	16	1.7	756	2730	3.1	0.068	2.3	62.5	588
Macaroni	14.0	3.09	0.85	517	140.30	239	26	4.0	323	1180	1.9	0.071	4.1	38.4	250
White bread	9.0	1.98	0.76	645	73.30	100	22	4.0	504	1323	1.6	0.136	10.0	45.4	250
Dried beans	5.0	1.10	0.33	31	5.40	61	5	2.0	907	3045	32.2	1.844	16.4	200.0	500
Dried peas	12.0	2.65	0.77	90	31.50	260	11	4.4	378	1305	11.1	0.317	3.8	90.9	227
Potatoes	3.3	.73	0.87	70	52.10	700	32	4.0	1361	1151	14.3	0.190	1.4	31.2	250
Spinach	6.3	1.39	6.62	67	20.70	466	67	60.0	720	150	14.9	0.483	2.1	14.9	17
Cabbage	3.0	.66	2.36	67	14.70	233	43	15.4	1361	424	14.9	0.672	4.3	23.2	65
Tomatoes	14.5	3.20	15.15	640	290.90	800	356	96.0	310	66	1.6	0.034	1.2	2.8	10
Bananas	10.0	2.21	2.27	275	245.30	367	169	10.0	454	440	3.6	0.041	2.7	5.9	100

[1] Chain store prices (except for soybean flour), Washington, D. C. April 5–10, 1934.
(and the nuts)

TABLE XIV—(*Continued*)

Food	Cost of food			Cost of 100 grams					Obtainable for 10 cents						
	Per pound	Per 100 g.	Per 100 calories	Ash	Calcium	Fat	Protein	Nitrogen free extract	Weight	Energy value	Ash	Calcium	Fat	Protein	Nitrogen free extract
	Cents	*Cents*	*Cents*	*Cents*	*Dollars*	*Cents*	*Cents*	*Cents*	*Grams*	*Calories*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
Oranges	5.0	1.10	2.08	220	24.40	550	138	9.6	907	482	4.5	0.410	1.8	7.2	104
Apples	8.0	1.76	2.93	600	211.70	360	450	14.0	567	341	1.7	0.047	2.8	2.2	71
Sugar	5.0	1.10	0.27	—	—	—	—	1.1	907	3727	—	—	—	—	1000
Eggs	18.0	3.97	2.51	400	59.20	38	27	—	252	398	2.5	0.168	26.3	37.0	—
Milk	6.5	1.43	2.01	200	12.30	35	42	28.0	699	497	5.0	0.840	28.5	23.8	36
Cheese	23.0	5.07	1.12	150	5.40	14	17	1700.0	196	894	6.6	1.844	71.4	59.0	1
Butter	31.0	6.83	0.86	227	454.90	8	680	—	147	1164	4.4	0.022	125.0	1.5	—
Lard	9.5	2.09	0.22	—	—	2	—	—	476	4450	—	—	500.0	—	—
Smoked ham	15.0	3.31	0.77	70	—	9	20	—	300	1300	14.3	—	111.1	50.0	—
Veal cutlets	43.0	9.48	6.12	855	—	124	48	—	105	163	1.2	—	8.1	20.0	—
Leg of lamb	25.0	5.51	1.92	550	—	24	29	—	182	520	1.9	—	41.6	34.4	—
Round steak	25.0	5.51	2.99	500	—	52	26	—	182	335	2.0	—	19.2	36.1	—
Peanuts (shelled)	30.0	6.61	1.17	330	93.06	17	26	30	151	855	3.0	0.107	58.4	39.2	33
Pecans (shelled)	100.0	22.04	2.89	1470	247.60	31	200	165	45	346	0.7	0.040	32.3	5.0	6
Walnuts (shelled)	60.0	13.23	1.82	778	148.70	21	72	114	75	549	1.3	0.067	48.7	13.9	9
Almonds (shelled)	100.0	22.04	3.30	1100	92.26	40	105	144	45	303	0.9	0.108	24.9	9.5	7

equaled or surpassed in ash or mineral content by bran (6.06%), rice polish (7.13%), and wheat germ (5.15%).

Cost of calcium in soybean flour. "Calcium is one of the most difficult things to get in any adequate quantity in any low cost diet" said Dr. Alice F. Blood (1917), then professor of nutrition, Simmons College, appearing before the Health Committee of the Massachusetts Legislature. She further said that "when families cannot use suitable amounts of milk—liberal amounts of milk—and fruit and vegetables, as is unfortunately true with the present prices for a good many people, the importance of even a small amount of calcium in the food is not to be overestimated." According to the data shown in the tables of analyses and of cost (Table XIV), it is quite evident that soybean flour is one of the cheapest sources of calcium.

Cost of carbohydrates in soybean flour. Carbohydrates in the form of soybean flour cost 5.5 cents per 100 g. Many foods are cheaper sources of carbohydrates, for example, white flour, 1.4 cents; corn-meal, 1.2 cents; macaroni, 4.0 cents; bread, 4.0 cents; and sugar, 1.1 cents. Carbohydrates are mainly the energy-forming constituents of foods. Energy, however, is derived from fat and proteins as well. Hence, soybean flour is one of the cheapest sources of energy, being surpassed in this respect only by corn-meal and lard at the relative prices given in Table XIV. For the same sum of money a greater weight of food can be bought in the form of soybean flour than in the form of any other food listed in Table XIV, except white flour, corn-meal, potatoes, dried beans, sugar, oranges, and cabbage.

The Use of Soybean Flour in Baking

Experiments in the use of soybean flour for making bread have also been conducted by Costa (1927) and by Fiehe (1925). Our own experiments show that soybean flour in any proportion up to 30% can be used with flour, white or whole wheat, not only for making bread but also for cake and other baked products. The method used in making bread was essentially that of the American Association of Cereal Chemists (Blish, 1928), with the exception that best results were obtained when a larger amount of yeast and of shortening was used and the period of fermentation was somewhat shortened. The dough temperature when mixed should be 80°–85° F. The addition of relatively small amounts of soybean flour (up to 10%) to white flour may be made without changing the regular baking method, although better results will be obtained by using the larger proportion of yeast and shortening.

The following formula and method was used in making white and whole wheat breads containing 20% soybean flour.

FORMULA AND METHOD FOR MAKING SOYBEAN BREAD [1, 2]

	Grams	%
Flour	260	80
Soybean flour	65	20
Yeast	15	5
Shortening	15	5
Sugar	10	3
Salt	5	1.5
Malt extract	5	1.5
Water	190	58 (variable)

[1] The amount of soybean flour in bread may range from 3 to 30 per cent of the total flour.
[2] Percentage figures are based on total flour (flour + soybean flour) = 100.

Mix for 3 minutes in a mechanical mixer; ferment at 30° C. (86° F.); punch after 45 minutes; pan after 15 minutes; proof for 55 to 60 minutes; bake at 230° C. (446° F.) for 30 minutes.

FORMULA AND METHOD FOR MAKING WHOLE WHEAT BREAD [1, 2]

	Grams	%
Whole wheat flour	325.0	100.0 [3]
Yeast	6.5	2.0
Malt extract	5.0	1.5
Milk (dry skim)	11.4	3.5
Sugar	10.0	3.0
Salt	6.5	2.0
Shortening	10.0	3.0
Arkady	0.8	0.25
Water	208.0	64.0 (variable)

[1] American Institute of Baking—private communication.
[2] This formula was used as the basic method for incorporating soybean flours.
[3] Percentage figures of components based on flour = 100.

Mix for 12 to 15 minutes in mechanical mixer; maintain the temperature of the dough at 79–80° F.; ferment for 2¾ to 3¼ hours.

About 20 samples of commercial soybean flour were baked, the amount of soybean flour used being 3%, 10%, 15%, 20%, 30%, and even 35% respectively, of the wheat flour. Figure 1 shows how the various soybean flours affected the quality of the loaf, indicating that soybean flours differ materially in their action when mixed with wheat flour.

For informative purposes the composition of representative flours and of breads made from them is shown in Tables XV and XVI.

Breads made with 20% soybean flour and 80% white or whole wheat flour are illustrated in Figures 2 and 3, and were included in Table XVI simply because they seem to represent a fair average of what a soybean

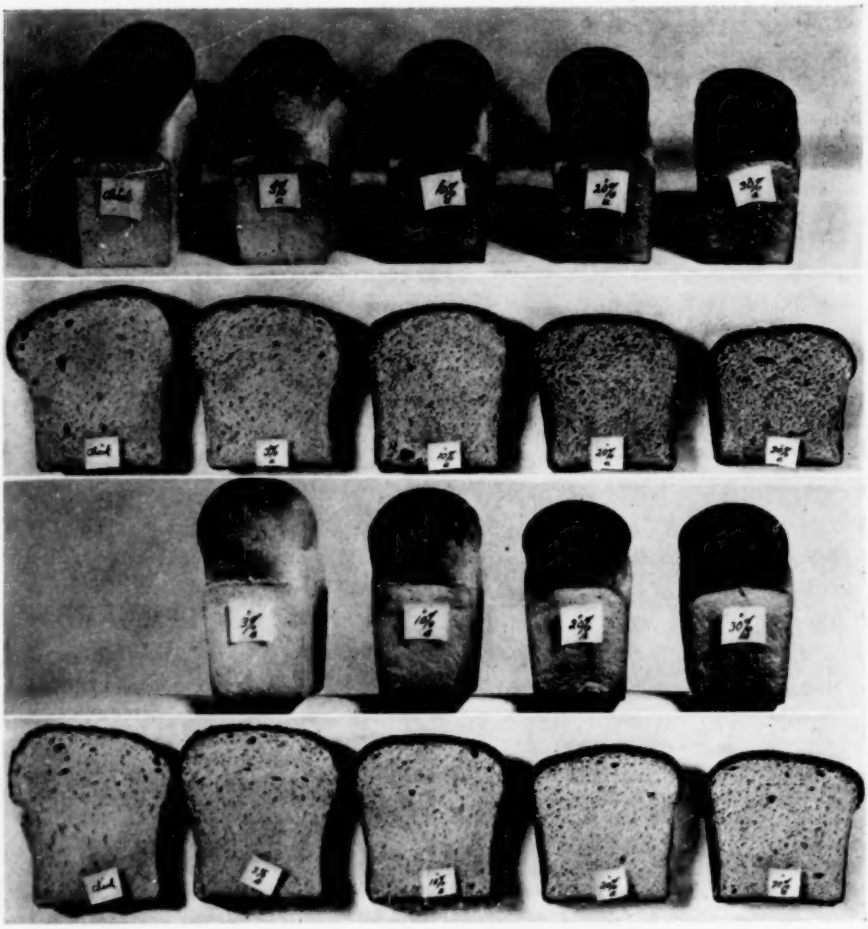

Fig. 1. Bread made from 2 commercial soybean flours—3, 10, 20, 30% soybean flour used.

TABLE XV
COMPOSITION OF REPRESENTATIVE FLOURS [1]

Kind of flour	Percentage of					
	Moisture	Ash	Fat	Fiber	Protein	Carbohydrates
White flour	12.01	0.48	1.45	0.22	11.69	74.15
Whole wheat flour	12.07	1.68	2.76	2.42	12.18	68.83
Wheat flour (clear)	12.72	0.74	1.99	0.30	12.61	71.64
White rye flour	11.99	0.67	0.75	0.26	7.08	79.18
Dark rye flour	11.59	1.80	1.46	0.97	13.28	71.14
Soybean flour (high fat)	7.16	4.72	21.46 [2]	2.38	40.25	24.03
Soybean flour (low fat)	7.79	5.73	7.34 [2]	2.96	47.56	28.62

[1] Typical of their respective classes. Average values from data obtained in the Cereal Laboratory, Bureau of Chemistry and Soils.
[2] Includes lipoids.

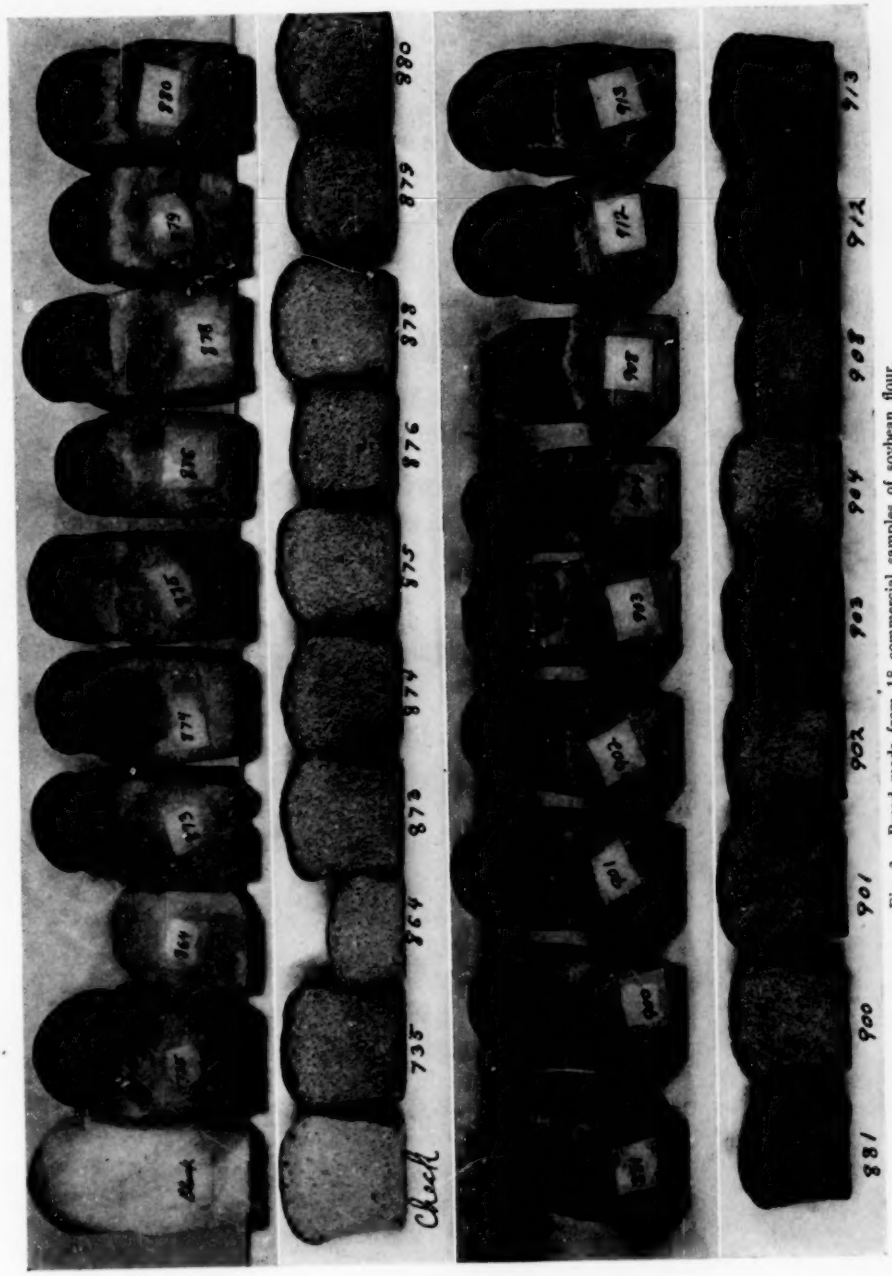

Fig. 2. Bread made from 18 commercial samples of soybean flour.
20% soybean flour.
80% wheat flour.

TABLE XVI

COMPOSITION OF REPRESENTATIVE TYPES OF BREAD [1]

Kind of bread	Percentage of					
	Moisture	Ash (Salt free)	Fat	Fiber	Protein	Carbohydrates
White flour (wheat)	36.83	0.36	2.47	0.33	8.21	50.74
Whole wheat	39.70	1.56	3.73	1.67	8.73	43.36
White rye [2]	38.01	0.55	1.15	0.40	7.96	50.85
Dark rye [2]	37.88	0.82	1.31	0.57	9.46	48.88
Soybean (high fat) [3]	39.95	0.89	4.91 [5]	0.59	11.40	41.27
Soybean (low fat) [3]	40.03	1.02	3.09 [5]	0.67	12.34	41.85
Whole wheat-soybean [4]	39.35	1.74	6.05 [5]	1.52	12.28	37.64

[1] Average values obtained by the Cereal Laboratory, Bureau of Chemistry and Soils.
[2] 33⅓% rye flour—66⅔% clear flour.
[3] 20% soybean flour—80% patent flour.
[4] 20% soybean flour—80% whole wheat flour.
[5] Includes lipoids.

bread should be. Bread made with 20% soybean flour and 80% white flour contains a somewhat higher percentage of water and about 150% more ash, and 40% more protein than white flour bread.

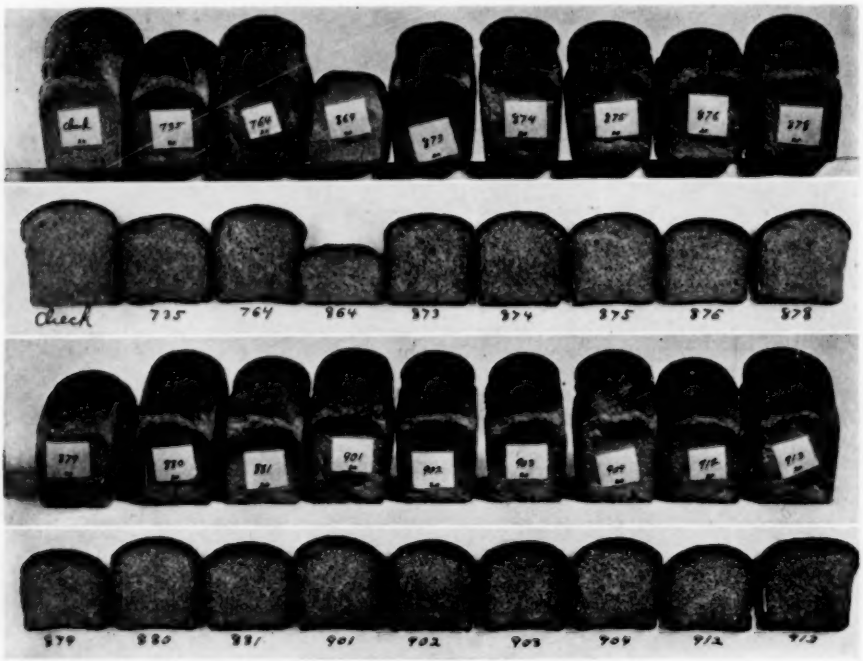

Fig. 3. Bread made from 17 commercial soybean flours.
20% soybean flour.
80% whole wheat flour.

Bread made from a mixture of 20% soybean flour and 80% whole wheat flour contains 40% more protein than ordinary white flour bread and has over 380% higher mineral content (exclusive of common salt).

Assuming a per capita consumption of 250 g. of bread per day, the consumption of bread containing 20% soybean flour means an increased intake during the year of more than 400 g. of minerals and 3,300 g. of protein, besides of course an increase in vitamins. The more general use of soybean flour in baked products of all kinds may in time increase the total consumption of wheat flour for it would then not be necessary to use so much of foods other than bread in order to supply the body with the essential nutritional elements. A much larger proportion of the diet could be composed of cereal products, if they contained soybean flour. The desirability of producing a new bread, one with special appetite-appeal, was recently stressed by James F. Bell, the president of General Mills, Inc.,[1] when, deploring the enormous decrease in bread consumption (27%) during the past quarter of a century, he wrote, " The way back is through the palate. The appeal must be made to the appetite. The old type of product, the old styles, the old methods will not avail. We must tax our initiative, resourcefulness and ingenuity to create and present new baked products with better flavor and appeal."

A well-baked soybean bread possesses an attractive crust, a rich cream-yellow crumb and has an agreeable aroma and taste, in other words, it has the appetite-appeal.

Effect of enzymes of soybean flour on bread

Soybean flour contains diastatic and proteolytic enzymes (Bruère and Chevalier, 1933) as well as urease in an active form. To a certain extent, the presence of urease indicates positive proteolytic and diastatic activity. These enzymes have an effect in baking similar, in a way, to that produced by the addition of 0.5 to 1.0% malt flour. In other words, fermentation is accelerated by the use of soybeans.

Our results show in general that soybean flours with low urease content yield bread of low volume, and vice versa (see Table XVII). Of the 18 samples of soybean flour used in baking bread, with a mixture of 20% soybean and 80% white flour, only 2 samples (Nos. 735 and 874) low in urease yielded a bread of large volume. On the other hand, every soybean flour with high urease content produced a satisfactory loaf.

Digestibility of soybean bread. Ducceschi (1927) has shown that bread made with 10% soybean flour and 90% white flour is utilized by the body fully as well as is white bread. With 20% soybean flour bread, the coefficient of utilization was as follows: protein, 83.9; fat,

[1] Open letter by James F. Bell, April 12, 1934.

94.1; carbohydrates, 96.4; minerals, 68.6. According to Holmes (1918), soybean protein is 85% digestible, a figure which compares favorably with that for cereal proteins.

TABLE XVII

CORRELATION OF VOLUME OF LOAF AND UREASE CONTENT OF SOYBEAN FLOUR USED IN MAKING BREAD

Soybean flour		Volume of loaf made with		
Sample No.	Urease content [1]	20 percent soybean flour	30 percent soybean flour	35 percent soybean flour
		Cc.	*Cc.*	*Cc.*
902	5.2	490	410	350
901	4.6	520	455	413
903	4.6	475	390	—
875	4.1	470	410	378
904	3.6	450	420	323
878	3.5	465	385	385
913	3.5	475	405	
873	3.2	455	390	
900	3.0	470	410	
912	2.0	455	370	
908	1.8	380	315	
879	1.4	405	325	
735	1.0	470 [2]	400	
880	0.9	415	350	
864	0.9	275	225	
874	0.3	465 [2]	350	
881	0.2	405	295	
876	0.2	380	285	

[1] Cc. N/10 ammonia.
[2] Exceptions, or out of line.

Johns and Finks (1921) found that the use of 15 to 25% soybean flour produced a palatable and nutritious loaf and that the mixture of protein in such bread is more efficient than the protein of white bread alone. He found also that such a bread contains an abundance of water-soluble vitamin B, and for the same amount of food consumed soybean bread diets are two to three times as efficient as wheat bread diets.

According to Westl (1927) the use of 20% of soybean flour gives a greater biological value to the bread protein; increases the nutritive value; and provides a tasty and satisfactory loaf, which remains fresh longer. When no more than 10% soybean flour is used in the mixture, the bread produced therefrom does not differ appreciably in taste from ordinary bread.

Increased absorption claimed for soybean flour. Some bakers claim that the use of soybean flour in bread-making increases the water absorption capacity. According to Bell (1933) 1 pound of soybean flour per sack (280 pounds) of white flour will require 2 pounds extra water,

and further the keeping quality of bread is somewhat enhanced. Similar statements are found in Food Manufacture (Anon. 1932a), where it is claimed that 1 to 1½% of ordinary soybean flour increases the keeping quality of bread.

Our results do not substantiate the statements made above regarding the absorption capacity or the necessity of using more water. True, our experiments were conducted with a much larger amount of soybean flour, but whether 3% soybean flour or 30% was used the absorption was essentially the same as when no soybean flour at all was used. In other words, it was found that soybean flour did not affect the absorption to any appreciable extent. This statement refers, however, to soybean flour prepared from whole beans and that made from the press cake. Soybean flour prepared by treatment with a dilute solution of sulfurous acid and subsequent extraction with a fat solvent did appreciably affect the absorption. With the addition of 3% of such fat-extracted soybean flour a wheat flour with 60% absorption required about 70% water; with 20% soybean flour the absorption was about 77%, and with 30% soybean flour a little more than 90%. However, it was found impossible to make a presentable loaf of bread with much more than 10% of this fat-extracted soybean flour.

Ordinary wheat flour bread (pup loaf) retains approximately 20% of the water used in doughing. When fat-extracted soybean flour is used to the extent of 20%, the water retained by the loaf is about 30% of that used in doughing. In other words most of the extra water added withstands the baking temperature and is retained by the loaf.

Our results are corroborated by Dietz (1933), who found that the use of 1% and 3%, respectively, of high-fat soybean flour did not increase the amount of dough but shortened the period of fermentation 4 to 7% and decreased the volume of the loaf 5 to 9% respectively.

Cost of soybean bread. The cost of the flour used in bread making averages generally less than one-quarter of the average price the consumer pays for bread. When the baker pays about $6.50 for a barrel of flour, which will yield approximately 300 loaves, the cost of flour per loaf is 2.17 cents. A mixture of 20% soybean flour (at five cents a pound) and 80% white flour would cost approximately $7.16 per barrel, or 2.39 cents per loaf. For every $1.00 per barrel increase (or decrease) in the price of the flour to the baker, there is a difference of one-third of a cent in the cost of the loaf. The use of 20% soybean flour would increase the cost to the baker less than one-quarter cent per loaf (.23 cent), a difference which would no doubt often be absorbed by the baker himself.

Conclusions

The soybean is a relatively new crop in the United States. It is one of the most important crops available to man and beast and can be successfully grown under a variety of climates. For hundreds of millions of people in certain parts of the globe it is the chief source of protein and possibly also of vitamins and minerals. Soybeans can be converted into flour, which in turn can be used with wheat flour in making bread, cake, cookies, pies, doughnuts, etc.

Soybean flour is a concentrated, wholesome, nourishing, and economical food. It is rich in protein, not only in quantity but also in quality. It is rich in fat, in minerals, and in most of the known vitamins. It is a cheap source of proteins, fat, minerals and energy. It is alkaline in reaction. When mixed with wheat flour in any proportion not exceeding 20% of the mixture, it makes a most appetizing, attractive, and nourishing loaf of bread.

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CEREALS IN NUTRITION TODAY

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The Program Chairman has asked that I discuss cereals as foods from the viewpoint of a nutritionist. He has suggested that particular attention be given to the newer developments in the field. Several equally specialized and important points exist from which one might panoramically survey cereals. The treatment which I expect to give the subject is simply an inventory of the nutritional aspect.

The subject of nutrition and that of dietetics have much in common but are not identical. M. S. Rose (1935) of Columbia University, in an excellent review of the teaching of nutrition in colleges, has differentiated the two fields essentially as follows: Nutrition deals with the scientific laws governing life processes, while dietetics is concerned with the practical application of those laws to individuals or groups of humans in health and disease.

Cereals, and foods made from cereal grains constitute one of the five groups into which it is customary and convenient to classify most of the items of our dietaries. These food groups may be listed as follows:

1. Cereals (bread, "breakfast foods," crackers, cookies, pastries, macaroni, etc.).
2. Dairy products (milk, cheese, and ice cream).
3. Vegetables and fruits (fresh, canned, and/or dried).
4. Fats and sweets (butter, lard, vegetable shortening, sugar, syrup, candy, sweetened preserves, etc.).
5. Meat and eggs (beef, pork, lamb, poultry, marine products, and eggs).

For purposes of this presentation the word cereals, unless otherwise qualified, is used to designate collectively all forms of cereal grain products including bread of all kinds, the so-called breakfast-food cereals, crackers, cookies, cakes, the macaronies and many other grain foods as we know them in our food industries and at the dining table. The cereal grains for this consideration are six in number, namely, barley, corn, oats, rice, rye, and wheat. Composition of the most common food products from each grain are indicated in Table I.

One cannot proceed with systematic consideration of the nutritional aspects of a food or group of foods without first defining nutritional essentials. An animal, human or otherwise, requires air, water, and groups of food substances which are classed as proteins, carbohydrates,

TABLE I

COMPOSITION OF SOME COMMON PRODUCTS OF DIFFERENT GRAINS[1]

	Polished rice	Wheat		Rye flour	Pearled barley	Cornmeal, new process	Oatmeal
		Patent flour	Graham flour				
	%	%	%	%	%	%	%
Carbohydrate	76.0	75.3	74.6	78.7	77.8	78.5	67.5
Protein	7.2	11.9	12.6	6.8	8.5	7.8	16.1
Fat	.2	1.6	.4	.9	1.1	1.3	7.2
Ash	.4	.5	1.7	.7	1.3	.6	1.9
Moisture	12.3	10.5	8.6	12.9	11.3	12.0	7.3

[1] From page 27, "Nutrition and Physical Fitness," 2d edition, by Dr. L. Jean Bogert, published by W. B. Saunders Company (1935).

fats, minerals, and vitamins. Cereals, like all other foods, excel in certain respects more than in others. An abbreviated summary of nourishment provided by cereals is given below:

Cereals are prominent contributors of:
Energy; carbohydrates; proteins; phosphorus; the blood forming minerals iron, copper, and manganese; and vitamin B.
Cereals are relatively low in:
Calcium and vitamins A, C, D, and G.

Today it is the concensus of the best opinion that at least forty distinct chemical substances are concerned in nutrition. These include atmospheric oxygen, water, about twenty-two amino acids which compose the proteins, about eleven mineral elments, a carbohydrate, a fatty acid such as linoleic or linolenic acid, and about six vitamins. A complete list including both the dispensable and indispensable nutritive substances follows:

Oxygen (atmospheric)
Water
Protein components—the amino acids glycine, alanine, valine, leucine, isoleucine, norleucine, phenylalanine, tyrosine, alpha-amino-beta-hydroxybutyric acid, serine, cystine, methionine, aspartic acid, glutamic acid, hydroxy-glutamic acid, ornithine, arginine, lysine, histidine, proline, hydroxy proline, and tryptophane.
Minerals—Ca, P, Mg, Na, K, Cl, I, S, Fe, Cu and Mn.
Carbohydrate—Starch and/or sugar.
Fat—Linoleic and/or linolenic acid.
Vitamins—A, B (or B_1), C, D, E, and G (or B_2).

If an animal can function without dietary intake of a certain substance that substance is called dispensable, and conversely if it must be present in the dietary the substance is called indispensable. Of the forty-odd substances all but about fourteen of the amino acids are considered indispensable. The later group includes,—atmospheric oxygen;

water; the amino acids leucine, isoleucine, phenylalanine, cystine, lysine, histidine, tryptophane, and W. C. Rose's (1935) recently announced new amino acid which for want of a shorter name must be called alpha-amino-beta-hydroxybutyric acid; the minerals calcium, phosphorus, magnesium, sodium, potassium, chlorine, iodine, sulphur, iron, copper, and manganese; starch or other carbohydrate; linoleic or linolenic acid; and vitamins A, B (B_1), C, D, E, and G (B_2).

In regard to the importance of cereals the American Medical Association (1930) recently expressed the following editorial opinion—

> "The cereal grains are the backbone of the nutrition of most of the races of the earth. They are, as a rule, the cheapest sources of food fuel; so that corn, wheat, rice, rye, barley and oat kernels are to be found constituting a third or often much more of the calory intake of the millions of persons involved."

I believe that statement is correct. As I shall indicate later, survey figures show that cereals are the primary source of carbohydrate, protein, and energy in our dietaries. Tables II defines for comparison 100-Calorie portions of a wide variety of common foods.

TABLE II

100-CALORIE PORTIONS OF FOODS IN COMMON MEASURES [1]

Apple sauce—⅜ cup	Flour, whole wheat, sifted—4½ tablespoons
Banana—1 medium	Ice cream, commercial—¼ cup
Beef, sirloin steak, lean, broiled—1 slice (2″×1.5″×¾″)	Lettuce—2 large heads
Bran (unwashed)—1 cup	Milk, whole—⅝ cup
Bread, white—2 slices (3″×3.5″×½″)	Oats, rolled, cooked—½ to ¾ cup
Bread, whole wheat, raisin—1 slice (3¾″×3⅛″×½″)	Orange juice—1 cup
Butter, 2 "squares"—(1¼″×1¼″×¼″)	Potatoes, white, baked—1 medium
Eggs, in shell —1⅓ eggs	Turnip greens, cooked—2½ cups
Flour, white sifted—4 tablespoons	Watermelon—1 slice (¾″×6″ diameter)

[1] From pages 59–93, "Laboratory Handbook for Dietetics," 3d edition, by Dr. Mary Swartz Rose, published by The Macmillan Company (1929).

Energy metabolism, the phase of nutrition which was first subjected to scientific investigation, requires readily oxidizable substances. Its purpose is to provide energy for either immediate or subsequent muscular movement. The unit of heat, a Calorie, affords a convenient means of speaking quantitatively of energy phenomena. One's Calorie requirement goes up rapidly with increasing exercise as indicated in Table III.

A gram of either carbohydrate or protein undergoing complete oxidation to its end-products, carbon dioxide and water, furnishes four Calories; while a gram of fat, because of its lower ratio of oxygen to carbon and hydrogen content, provides about nine Calories. In most American dietaries and in those of many foreign countries it is customary, and

TABLE III

ENERGY EXPENDITURE PER HOUR UNDER DIFFERENT CONDITIONS OF MUSCULAR ACTIVITY [1]

Form of activity	Calories per pound per hour	
	Man	Woman
Sleeping	0.43	0.40
Sitting quietly	0.65	0.60
"Light exercise"	1.10	1.02
"Active exercise"	1.88	1.75
"Severe exercise"	2.92	2.72
"Very severe exercise"	3.90	3.62

[1] From page 17, "Laboratory Handbook for Dietetics," 3d edition, by Dr. Mary Swartz Rose, published by The Macmillan Company (1929).

it is nutritionally satisfactory, that carbohydrates furnish about 70%, and that protein and fat each contribute about 15% of the total Caloric intake. The Calorie content of proteins, in contrast with that of carbohydrates and fats, is of secondary importance to the essential nitrogen which the proteins furnish the body.

According to the White House Conference publication figures (1932) which were based on Pearl's survey (1924), cereals furnish more protein to the American diet than do any of the other four classes of foods. Cereals provided 36%, meats 26%, dairy products 20%, and miscellaneous foods 18% of the protein. This is shown graphically in Figure 1. The proteins which contain all of the known amino acids are considered complete, those which lack one or more are called incomplete.

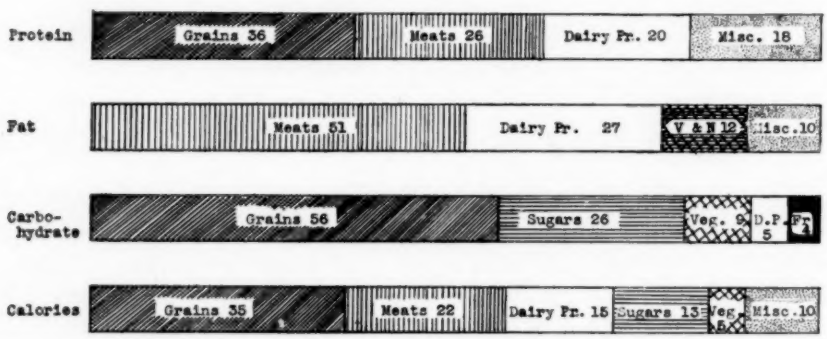

Fig. 1. Contributions to the protein, fat, carbohydrate, and Calorie phases of average United States dietary in terms of percentage for important food groups. Based on data from page 113, White House Conference on Child Health and Protection, "Growth and Development of the Child, Part 3, Nutrition," published by The Century Company. (V & N = Vegetables and Nuts; Dairy Pr. & D. P. = Dairy Products; and Fr = Fruits.)

Much information is lacking in regard to protein biochemistry and considerable new interpretation is needed in this field. Such products

as milk, eggs, and vital organs of animals closely approach completeness. Lean meats may be next in order of perfection, then cereals, and lastly the legumes. Soybeans are probably exceptionally better than other legumes. Recently Csonka (1935), of the federal Department of Agriculture, has undertaken the task of measuring the important amino acids in common food products. That program contrasts with the earlier and less practical work which was done on laboratory purified proteins.

That hordein of barley, zein of corn, and gliadin of wheat lack the dispensable amino acid glycine is not important. In contrast the total absence of the essential lysine from zein is thought to be of more consequence. Sherman (1933) expressed well the practical scientific view of the situation when he wrote—

> "It does not follow, however, from the fact that gliadin, hordein, or zein is inadequate as a sole protein food, that wheat, barley, maize, or their mill products would be correspondingly inadequate even if fed alone. Each of these grains (and of the staple mill products made from them) contains a mixture of proteins, and the other proteins with which gliadin, hordein, and zein are always mixed in wheat, barley and maize do not show these same peculiarities of chemical structure, so that we have no reason to fear that either lysine or tryptophane would ever be wholly lacking in any staple food product made from grain. Thus glutenin, which is always present in wheat flour, has been shown to be adequate for both maintenance and growth, even when it was the only protein in the diet. It is, however, only reasonable to expect that the mixture of proteins found in corn-meal or even wheat flour will be of somewhat less value in nutrition than an equal weight of the mixture of proteins which we find in milk, eggs, or meat.
>
> "Fortunately the proteins of milk are relatively rich in those amino acid radicles in which the grains are poor. Osborne and Mendel have found that their animals are not only maintained in health and vigor, but also make a normal rate of growth when three-fourths of their protein is zein and one-fourth is lactalbumin. If bread be made with milk instead of water, or if breakfast cereal or even corn-meal mush be eaten with cream or milk, the protein of the combination may have fully as high a value in nutrition as the average protein of ordinary mixed diet."

Of the minerals necessary in the dietary under typical conditions of American practice, cereals furnish in descending order 35% of the copper (Hodges and Peterson, 1931); 30.2% of the phosphorus; and 25.8% of the iron (Sherman, 1932). It is yet too early to thoroughly evaluate the full significance of copper as a food element. The fact seems well established, however, that the higher copper content of the less refined cereals may serve a very useful role in aiding the utilization of iron for hemoglobin production. The amount of iron furnished by cereals is equalled or exceeded by only the fruit and vegetable group of foods. Early indications are that when *available* rather than *total* iron is recognized that cereals may be given even higher relative standing than is at present accorded them.

Cereals are and have been long recognized as an important source of dietary phosphorus. The phosphorus, iron, calcium, and copper content of whole-grain cereal products is approximately three to five times

higher than in so-called refined products. Several years ago Sullivan (1933) presented a thorough review of the prominent and rare minerals in wheat, wheat flour, and bread. Only recently it has become known that one mineral element which may occur in various plants, affects animals deleteriously. That element is selenium, a close relative of sulphur. This morning Dr. Jones (1935) gave us an excellent summary of that subject. It seems quite unlikely that the amount of grains exported from the restricted, affected, arid, or semi-arid districts will be of significance. The Federal Bureau of Chemistry and Soils has the problem well in hand and can be relied on to assure the public that no harmful grains are milled.

Mineral metabolism, especially as regards calcium and phosphorus, has been a subject of extraordinary interest in the cereal field. Edward Mellanby of England, in 1921 propounded the theory that most cereals contain a material which interferes with calcification. He proposed the name "toxamine" for the substance and claimed that it acted in the opposite manner from that of vitamin D. Mellanby wrote that the negative or decalcifying effect of the "toxamine" in cereals could be counteracted or destroyed by any one of four procedures, namely, (1) autolysis, (2) mild hydrochloric acid hydrolysis, (3) ultraviolet irradiation, or (4) the direct addition of vitamin D. The ultraviolet and direct methods are now used on a commercial scale. About one year ago Bruce and Callow (1934) of England reported that the so-called decalcifying effect of high cereal diets was in large part due to the unavailability of the phytin phosphorus—the form in which much of cereal phosphorus exists. In this country Harris and Bunker (1935) of Massachusetts Institute of Technology, have analyzed many different samples of corn and find that the proportion of phosphorus in phytin form varies from less than 10 to more than 70 per cent of the total phosphorus. They find no correlation between the phytin phosphorus value and the tendency of the various corn samples to produce experimental rickets in animals. Bacharach (1935) of London, has within the last month published to the effect that the findings of Bruce and Callow "enables us to dispense with the toxamine theory first propounded by Mellanby." It is probably too early to try to reach a final judgment in this matter. More evidence is needed.

Vitamin chemistry and physiology has occupied extensive interest in the last twenty years. It is expected that wide and justifiable interest will be directed to that subject for many years to come. That vitamins may have been unduly publicized in some quarters in no way detracts from their nutritional importance. The antineuritic nerve-nourishing, appetite-stimulating vitamin B (B_1) is likely the most important vitamin

in cereal products. The whole-grain cereals, rolled oats and whole wheat products, are the richest widely consumed sources of that factor. Federal Department of Commerce industrial production survey figures (1933) indicate that the amount of rolled oats milled for human use exceeds that of whole-wheat breakfast foods and whole-wheat flour combined. These three are the chief whole-grain foods. The embryo of wheat, and likely that of other grains, is especially rich in vitamins B (B_1), and E, and is also a very good source of vitamins A and G (B_2). Only the germ of wheat and corn are commercially available in purified form for laboratory work and for food purposes.

Further members of the so-called vitamin B complex seem to exist. Two of these are now called vitamins B_3 and B_4. It is very probable that vitamin B_4 will hold considerable interest in the cereal field and for the poultry feeder.

Vitamin and mineral enrichment of cereals is a growing practice. Cereals so enriched are more nourishing than the same products without those additional food adjuncts. Scientific appreciation of minerals and vitamins is well developed; the problem now is one of economic distribution. The practice should develop slowly and sanely, and with truly conservative educational publicity.

For reasons of economy, and because of their physical character the cereals are well adapted to act as vehicles for carrying certain vitamins and minerals inexpensively, conveniently, and automatically to the people who need those substances most. Accordingly, the increasing policy of enriching cereal products with vitamins B (B_1) and D, and with the minerals calcium, phosphorus, and iron. Such improvement must be held within reasonable bounds.

Digestibility in non-scientific parlance means the ease, speed, and/or comfort of digestion of foods. In that sense, as well as in ultimate coefficient of digestibility, cereals rank very high. Maile and Scott (1935) of London, have recently further confirmed the digestibility of white bread by X-ray observation of stomach-emptying time in human subjects. They found evacuation complete after periods of the following respective durations,—2 ounces sugar—1.5 hours, ½ pint rich raw milk—3.5 hours, 4 ounces white bread—3.75 hours, 4 ounces emulsified butter—6 hours, and 4 ounces boiled beef—4.0 hours.

Cereals rank high as sources of economical nourishment. This is especially true as regards their energy, protein, iron, and vitamin B content. Several well known dietary lists have been formulated with due appreciation to economy as well as to nourishment value. United States Department of Agriculture Circular No. 296 entitled "Diets at Four Levels of Nutritive Content and Cost" (1933) by Stiebling and

Ward, may be cited as outstanding in that regard. Table IV gives the distribution of Calories in their suggested diets at four levels of cost. It shows how cereal consumption increases as the budget allowance declines. That is probably the best reason why the attitude of persons interested in public welfare is becoming more favorable toward supplementation of cereals with important nutritional adjuncts.

TABLE IV

DISTRIBUTION OF CALORIES IN THE 4 SUGGESTED DIETS [1]

Type of diet	Calories derived from—					
	Bread, flour, cereals	Milk, cheese	Vegetables, fruits	Fats	Sugars	Lean meat, fish, eggs
Restricted diet for emergency use	42	15	13	16	9	5
Adequate diet at minimum cost	32	24	14	15	7	8
Adequate diet at moderate cost	23	24	18	16	8	11
Liberal diet	14	25	18	16	8	19

[1] From United States Department of Agriculture Circular No. 296, November, 1933. (Page 37.)

Certain data on adequate diet at minimum cost contained in that federal circular were adapted by Chaney and Ahlborn (1934) for calculations of a weekly dietary list for a family of five including man, woman, and children 13, 5, and 3 years respectively. "Emergency" diets are not usually adequate, and adequate nutrition on moderate or liberal budgets is not a difficult problem for a good dietician. We are, therefore, interested chiefly in adequate nutrition at minimum cost. Let us now give our attention to the food market order for the above described family of five for one week. In Table V the food products are itemized, and the cost is listed. Table VI shows the percentage cost and contribution to the energy, protein, calcium, phosphorus, and iron aspects of the total as it applies to each food group. The costs are based on prices prevailing in a national-chain outlying grocery store in Chicago, on May 15, 1935. There are, of course, other less tangible properties inherent in certain foods which are desirable and which have monetary value. These include vitamins and unique flavors. Let us analyze the nutritional economics of that list.

Figure 2 shows the same information graphically. Cereals costing 18% of the total provide 34% of the calories, 31% of the protein, 6% of the calcium, 25% of the phosphorus, and 23% of the iron. In every respect except that of calcium there is a distinct "plus" value, that is to say, a material excess in contribution over cost. Similar con-

sideration of the other food groups is interesting and enlightening but time does not permit us to go into that now.

TABLE V

A Low-Cost, Nutritionally Adequate, Market Order for One Week for a Family of Five

	Am't.	Cost [1]		Am't.	Cost [1]
Cereals		$1.66	*Fruits*		$ .55
Bread, white	4 lbs.	.28	Prunes, dried	1.5 lbs.	.23
Bread, whole wheat	4 "	.32	Apples	4 "	.32
Cornmeal	4 "	.27			
Farina	2 "	.22	*Fats*		$1.12
Flour, patent	2 "	.12	Butter	1 lb.	.32
Rice, polished	2 "	.38	Lard	1 "	.17
Rolled Oats	1 "	.07	Bacon	1 "	.40
			Peanut butter	½ "	.11
Dairy Products		$2.66	Cod liver oil	3 oz.	.12
Cheese, cheddar	1 lb.	.29			
Milk, fresh	21.5 qts.	2.37	*Sweets*		$ .26
			Sugar	2 lbs.	.11
Vegetables		$1.29	Molasses	1.5 "	.15
Potato, white	13 lbs.	.15			
Beans, navy dried	2 "	.11	*Meats and Eggs*		$1.68
Tomatoes, canned	5 "	.43	Beef, round lean	2 lbs.	.66
Cabbage	2.5 "	.08	Pork, medium fat	2 "	.58
Carrots	3 "	.18	Eggs	1.5 doz.	.44
Lettuce, head	1 "	.10			
Spinach	1.5 "	.09			
Onions	2 "	.15	Total Cost of Entire Order		$9.22

[1] Cost data from a Chicago retail grocery store, May 15, 1935. All other data from "Nutrition," by Chaney and Ahlborn, published by Houghton Mifflin Company (1934).

Food fads, and other erroneous notions have frequently concerned cereals. One quite prevalent idea at this time is to the effect that carbohydrates and proteins must not be eaten at the same meal because carbohydrates require an alkaline medium and the proteins an acid medium for their digestion. Rehfuss (1934) has recently investigated that subject and has concluded as follows—"There is no evidence either in the literature or in my investigation to lead me to believe that proteins and carbohydrates are incompatible in the stomach."

Another fallacious idea is that cereals are simply sources of energy and nothing more. The tables and figures shown above should forever dispell any such thought. Certain faddists have chosen to believe that we should eat only those foods which leave an alkaline residue. While on this subject of acid-base balance it is appropriate to mention that Davidson and LeClerc (1935) have very recently outlined a new method for estimating the acid-base balance in foods.

Bauer (1935) of Boston has recently written that "The 'acid

system' is a myth," "One need make no conscious effort to maintain a basic diet in an arthritic person any more than in a normal one. A well-balanced, well-mixed, adequate diet in no way disturbs the acid-base balance of the body." Some people claim that all should eat unre-

TABLE VI

A LOW-COST, NUTRITIONALLY ADEQUATE, MARKET ORDER FOR A FAMILY OF FIVE [1] (INCLUDING MAN, WOMAN, AND CHILDREN 13, 5, AND 3 YEARS OF AGE RESPECTIVELY)

Contribution	Food groups					Total for week	Total for day	Standard for day
	Cereals	Dairy products	Vegetables and fruits	Fats and sweets	Meat and eggs			
Cost								
Amount	$1.66	$2.66	$1.84	$1.38	$1.68	$9.22	$1.32	—
% of total	18.0	28.8	20.0	15.0	18.2	—	—	—
Calories								
Amount	26,581	16,319	11,702	18,122	5,936	78,660	11,237	10,724
% of total	34	21	15	23	7	—	—	—
Protein								
Grams	827.8	806.7	395.4	135.0	466.1	2,631	375.9	331
% of total	31	31	15	5	18	—	—	—
Calcium								
Grams	2.51	28.99	4.51	1.81	0.87	38.70	5.53	4.36
% of total	6	75	12	5	2	—	—	—
Phosphorus								
Grams	12.93	22.29	10.17	1.89	5.38	52.66	7.52	5.64 to
% of total	25	42	19	4	10	—	—	7.14
Iron								
Mgms.	111.69	56.80	177.84	66.94	77.68	487.95	69.71	69.0
% of total	23	11	36	14	16	—	—	—

[1] The cost data are based on prevailing retail prices in a national chain grocery store in outlying Chicago, on May 15, 1935. All other data are from Chaney and Ahlborn's calculations and adaptations based on publication by Stiebling and Ward.

fined cereals, or that all should eat bran. Of these fancies Bogert (1935) has recently commented—"Either highly milled cereals or whole grains make good foods but, if the former are used, more milk, fruit and vegetables will be needed in the diet to make up for the deficiencies of the highly milled grains (lacking in vitamins, salts and fiber). Bran, when taken in large amounts by those with a sensitive intestine may do harm."

Educational material of the proper conservative type would go far in counteracting ridiculous thoughts and practices, and in educating the

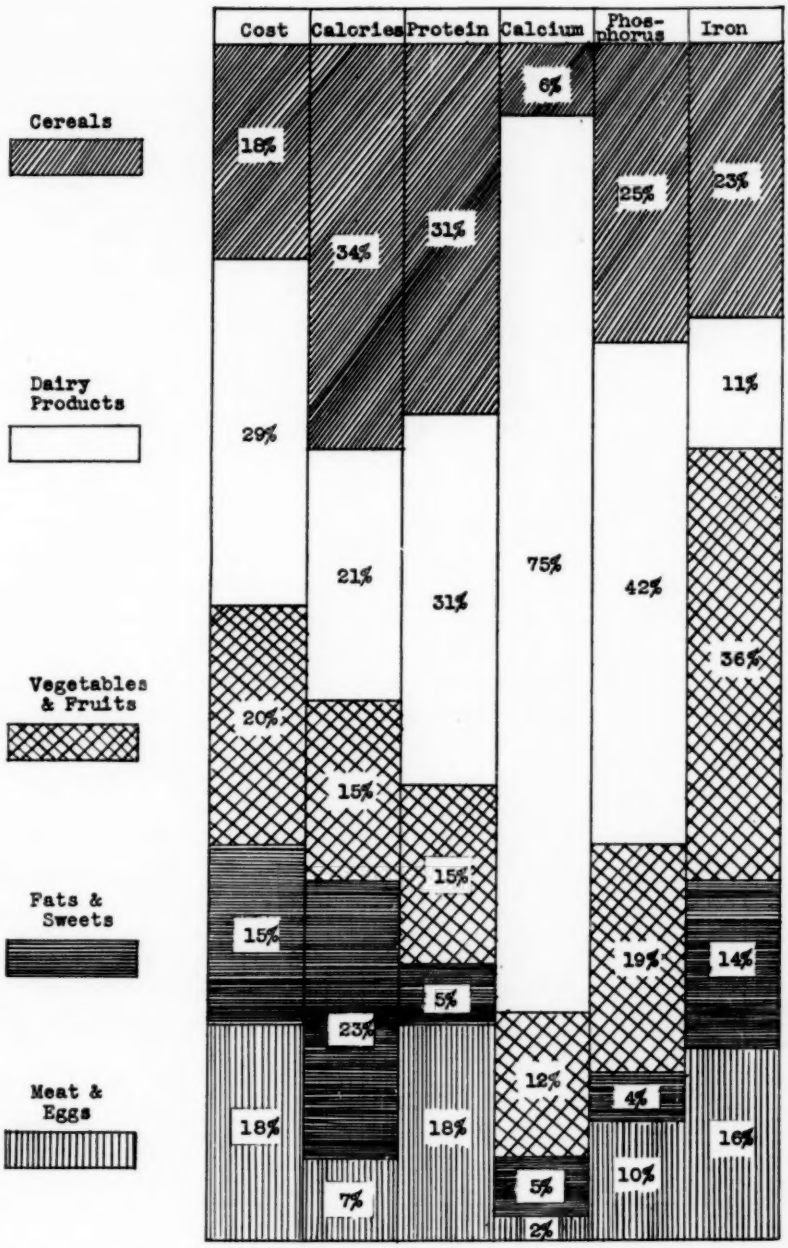

Fig. 2. Cost and nutritive contributions of important food groups in low cost, adequate dietary for five people. (The data on which this chart is based are shown in tables V and VI.)

public to the correct facts about cereals. Many food producers and industries have found it advisable to operate central institutes whose primary functions are particularly to convey to the public, through educational channels, knowledge of nutritional and dietetic virtues of the foods represented. Organizations are so engaged on a national scale in the fields of dairy products, marine foods, meats, poultry, and citrus fruits. Grains and cereals, in my opinion, might well be represented in a similar broad manner. There are many good things which need the telling in regard to cereals. A conservative yet aggressive educational program might be much in order as one means of placing and maintaining cereals in their just and proper place in the human dietary.

Conclusions

Cereal grain foods continue to provide approximately a third of the energy and protein; a quarter of the phosphorus and iron; and very appreciable proportions of the total vitamin B content of nutritionally complete yet economical American dietaries. In such adequate menus as planned by dietetic experts for greatest economy, cereal foods are present to the extent of more than one-half pound per adult per day.

As one compares the nutritional economics of cereals with that of other classes of foods it is readily apparent why cereals have long been called " the backbone of the nutrition of most of the races of the earth." There are many good reasons for expecting them to remain in that position.

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ASH OF FLOUR IN PHOSPHATED AND SELF-RISING FLOURS

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(Read at the Annual Meeting, June 1935)

The best method available so far for the determination of flour ash in phosphated and self-rising flours from commercial sources is that proposed by Gustafson.[1] This method has been found to be reliable on flours which have been freshly prepared or which have been stored under perfect conditions. However, several laboratories have found that under some conditions the method gives fictitiously high ash results on self-rising flour. A Georgia law requiring that all flours having an ash content in excess of 0.5% must be branded as low grade, and the fact that other states are considering similar legislation, makes it quite important that the method used for determining the original ash content of such flours be reliable.

Gustafson's procedure utilizes differences in density for separating the added mineral ingredients from flour when suspended in carbon tetrachloride and centrifugalized to aid the separation. Ash analysis is then made on the recovered flour after evaporation of the liquid. Examination of specific gravity tables shows these differences to be sufficiently great so as to allow a clean separation of ingredients even though the end products of a soda-phosphate reaction might be present. Modifications of Gustafson's method were suggested by Shuey [2] who recommended more agitation of the flour with the separatory liquid to break up lumpy or "shot-ball" flour, together with other refinements of the method. Both methods give satisfactory results on freshly prepared self-rising flour. The inconsistent results are evidently due to some change taking place during storage. We have attempted to determine what contributes to high ash results due to storage conditions and to develop some method for overcoming these difficulties.

It is not likely that a chemical reaction would take place between added minerals and the flour, although such reactions have been known to occur, or between flour and carbon tetrachloride. Neither is it likely

[1] Gustafson, C. G. A simple method for determining the ash content of the flour in self-rising and phosphated flours. Cereal Chem. **8**: 475–481 (1931).

[2] Shuey, G. A. A modified method for the removal of added ingredients from phosphated and self-rising flours in order to determine the ash content of the original flour. Cereal Chem. **12**: 289–293 (1935).

that peptization within a dry flour would affect the ash results. It is possible, therefore, to eliminate these factors, and to consider the cause of high ash contents of the flour separated from self-rising flour from a purely physical standpoint. It is common knowledge among those familiar with " shot-ball " flour that when a self-rising flour is stored under humid conditions the salt absorbs moisture from the atmosphere to such an extent that small, hard lumps are formed. Our experiments show " shot-ball " formation to be the chief cause of the failure of the method. Shuey [2] recognized the existence of " shot-balls," but no data were offered to support his recommendation for vigorous agitation.

Method and Materials

The work reported here was carried out using the Gustafson method except that two extractions were made as recommended by Shuey.[2] In many cases the results obtained were lower than the ash of the plain flour. It is apparent that foreign matter, silica, or other mineral constituents of flour were removed particularly from the lower grades of flour. This was a source of error recognized by both Gustafson and Shuey. In view of the enormously greater ash contents of certain samples from self-rising flours, no further refinement of our procedure was considered necessary. All ash results are reported here on a 15% moisture basis of flour.

Soft winter wheat flours from a large capacity mill were used. The majority of the work was done with a 40% patent, but a straight and a first clear were also included for a final check with flour grade. Phosphated flours were mixed using 0.5% phosphate flour weight basis. Self-rising flours were mixed using a standard formula in which to 100 parts of flour

1.5% soda (sodium bicarbonate),
1.875% phosphate (calcium acid phosphate), and
1.75% salt (sodium chloride) were added.

Both soda and salt were commercial products having added tri-calcium phosphate as a filler.

Room storage of flours was in a relatively dry cabinet near a bake oven. A humidor controlled at 95° F. and 85% relative humidity was used for storage in a moist atmosphere representing an extreme condition. All flours were scaled into ½ lb. cloth sacks, and after storage in the humidor they were allowed 3 days to come to equilibrium with room conditions before testing.

Experimental

Storage Conditions *versus* Ingredients of Self-Rising Flour

Preliminary experiments with a single self-rising flour showed that after 24 hours in the humidor sufficient moisture had been absorbed tc result in " shot-balls " having a soft granular feel when rubbed between the fingers, and after 9 days they had increased to be from 1 to 3 mm. in diameter. The larger lumps were a casing of dried dough surrounding recrystallized salt as had been previously observed in our laboratories. The testing of each ingredient alone and in combination with each other was then carried out using the percentage weight of each with flour. Times of storage in the humidor are indicated in Table I together with ash analyses by the Gustafson procedure, percentage of soda in the flours containing soda, and the P_2O_5 analyses of some of the separated flours.

TABLE I

Effect of Storage Conditions and the Individual Ingredients of Self-Rising Flour on the Ash of CCl_4 Separated Flour

A—Room Storage, B—24 Hour Humidor Storage, C—72 Hour Humidor Storage

Sample No.	Ingredient added to flour[1]	Ash[2]			Soda in self-rising flour			P_2O_5 in separated flour		
		A	B	C	A	B	C	A	B	C
		%	%	%	%	%	%	%	%	%
11	None (plain flour)	0.319	0.319	0.324	—	—	—	—	—	0.26
14	Phosphate	0.332	0.316	0.329	—	—	—	—	—	0.27
12	Soda	0.320	0.343	0.360	1.52	1.51	1.52	—	—	0.31
15	Soda+phosphate	0.316	0.357	0.409	1.49	1.47	1.45	—	—	0.46
13	Salt	0.314	0.840	—	—	—	—	—	—	—
17	Salt+phosphate	0.323	1.050	—	—	—	—	.22	.29	—
16	Salt+soda	0.331	1.040	—	1.48	1.49	—	.20	.19	—
18	Soda+salt+phosphate	0.348	1.010	—	1.46	1.42	—	.19	.29	—

[1] Weight of ingredient added was based on the percentage formula for self-rising flour.
[2] Ash of plain flour was 0.344%.

It may be noted from the data that under favorable storage conditions " A " no serious error in ash analyses was obtained whereas with storage for 24 hours under humid conditions " B " all samples containing salt exhibited a marked increase in ash content of separated flour. Examination of the " B " samples before and after separation showed that those containing salt had small, granular-feeling lumps whereas those with no salt present had a smooth feel. Analyses of ash, to which detailed reference is made later, showed a high chloride figure.

Analyses of the samples for total CO_2, reported as percentage soda, resulted in the conclusion that leavening power is not affected by the

moist storage conditions. The samples containing no salt were stored 72 hours in the humidor ("C" conditions). It may be noted that the P_2O_5 content of the separated flour is somewhat greater in those containing soda or phosphate and soda, and that these figures are parallel with a small increase in the ash of flours stored under "B" conditions. This may be evidence of reaction with flour constituents as some have suggested to the authors, but in view of the much greater effect of salt on flour ash, this factor was considered negligible.

From these data, it was established that salt is the material in self-rising flour causing a fictitious ash result. The mechanism of contamination prior to the separation of the flour can be considered to be due to the hygroscopic character of salt which results in absorption of moisture to form either a saturated solution on the surface of the salt or complete solution of the crystal. When the flour is dried out again, salt has been adsorbed on flour particles or small "shot-balls" are formed which are lighter than the separating liquid, thus explaining the appreciable quantities of salt in the separated flour. That this is the process is evident from the data in Table I and from those given later.

Effect of Moisture Content of Materials Before Mixing Self-Rising Flour

Since soda and phosphate were eliminated as the cause of high ash in self-rising flour analyses, only salt and flour were studied from the standpoint of their inherent moisture before mixing. The data were obtained for Table II using self-rising flours which were allowed to remain at room conditions for 9 days after mixing before being ana-

TABLE II

Moisture of Ingredients for Self-Rising Flour as Affecting the Ash of CCl_4 Separated Flour [1]

Flour condition		Normal	Wet	Dry
Flour moisture before mixing self-rising flour, per cent		13.4	15.1	1.46
		Ash of flour in per cent		
Normal salt	0.05% moisture	0.285	0.293	0.301
Wet salt	2.27% moisture	0.323	0.326	0.316

[1] The phosphate and soda had normal moisture contents.

lyzed for ash content. It will be seen that in no case was the ash of plain flour (0.34%) exceeded. From a commercial standpoint it is

significant that, even though wet flour and wet salt were used, the self-rising flours, when stored under relatively dry conditions, showed little or no adsorption of salt on flour particles or formation of "shot-balls" with a subsequent error in ash determination.

Variation of Methods

Attempts were made to disintegrate "shot-ball" self-rising flour by variations of the method as shown in Table III. In no case was the ash content lowered to that of the plain flour control figure. It is significant that more than double the true ash content was obtained when the self-rising flour was sieved through a T–325 mesh screen before CCl_4 separation, and that altering the density of the CCl_4 by addition of naphtha resulted further in a very small reduction of the error. These results support the contention that salt diffuses to flour particles where it is adsorbed and remains attached when attempts are made to separate it.

TABLE III

Variations of Mechanical Procedure with the CCl_4 Separation Method When Using "Shot-Ball" Self-Rising Flour

Series	Self-rising flour Number	Procedure	Ash
			%
A		Stored in humidor 24 hrs., small, soft granules	
	1	Before storage in humidor (soda = 1.44%)	0.327
	2	After storage in humidor (soda = 1.43%)	1.570
	3	Dried 1 hr. at 130° C., ground to pass T-100 screen	2.110
	4	Portion of self-rising flour sieved T-170, shot-balls discarded	0.665
	5	Portion of self-rising flour sieved T-170, 1st extraction with 90% CCl_4—10% naphtha; 2nd extraction with 85% CCl_4—15% naphtha	0.575
	5a	½ of flour on bottom of tube from 5, re-extracted with CCl_4	0.850
	6	Sieved T-325, CCl_4 extracted	0.883
	7	Sieved T-325, 90% CCl_4—10% naphtha extracted	0.699
	8	Sieved T-250, 90% CCl_4—10% naphtha extracted	0.840
B		Stored in humidor 9 days, 1–3 mm. "shot-balls"	
	1	Before storage in humidor	0.301
	2	After storage in humidor	2.700
	3	Ground to all pass T-60 screen	2.080
	4	Sieved T-60 screen, shot-balls discarded	1.190
	5	Self-rising flour ground in mortar and pestle	2.030
	6	Self-rising flour ground with CCl_4 in mortar and pestle	2.040

Flour Grade *versus* Storage Conditions

The three grades of flour, patent, straight, and first clear, were mixed into phosphated and self-rising flours and analyzed for flour ash

as shown in Table IV. The ash of the plain flours was obtained by the usual procedure for a point of reference. It will be observed that extraction of plain flours and phosphated flours with carbon tetrachloride probably removed some of the natural mineral constituents of the flour, particularly from the lower grades. More accurate methods were recommended by Shuey. Storage of plain and phosphated flours affected the ash figures by varying degrees, but all results were below the control ash figures. The separation of ingredients from room-stored self-rising flours (A) was complete as shown by ash figures lower than the controls. With the humidor-stored self-rising flours it is apparent that a very large error in ash is obtained. The grade of flour had no influence as a protecting agent against moisture absorption by salt.

TABLE IV

EFFECT OF FLOUR GRADE ON ASH OF PHOSPHATED AND SELF-RISING FLOURS
A—Room Storage, B—48 Hours Humidor Storage

	Per cent ash of CCl_4 separated flour					
	Plain flour		Phosphated flour		Self-rising flour	
Flour direct	A	B	A	B	A	B
Patent 0.344	0.342	0.322	0.330	0.340	0.329	1.38
Straight 0.401	0.381	0.391	0.395	0.380	0.390	1.30
1st Clear 0.550	0.512	0.529	0.486	0.517	0.495	1.39

COMMERCIAL SAMPLES

The flours listed in Table V were samples of plain and self-rising flours received from mills or retainer samples of plain and laboratory-mixed self-rising flours. The three representing commercially-stored products resulted in a high ash analysis whereas those from which atmospheric moisture was excluded during storage resulted in only a small increase in ash over their plain flour controls. These results serve to substantiate the method of storage in a humidor as being equivalent to conditions existing in the commercial handling of self-rising flours, and further establish the fact that when atmospheric moisture is excluded from self-rising flour, a true ash figure will be obtained. A loss of leavening power has occurred in all samples, but this is of a small order of magnitude compared with the large excess of ash.

The last column in Table V gives the NaCl content of the ash, based on the flour weight, when analyzed by the usual silver nitrate colorimetric method. The data show that the majority of the excess ash is due to salt.

TABLE V

ANALYSES ON COMMERCIAL AND LABORATORY-MIXED SELF-RISING FLOURS

Sample	Age	Plain flour ash	Soda in self-rising flour	CCl_4 separated flour: Ash	CCl_4 separated flour: NaCl in ash (Flour basis)
		%	%	%	%
A. Commercial samples received—stored with exposure to atmospheric conditions					
WE-1	1 Year	[1]	1.36	0.86	0.16
WE-2	2 Years	[1]	1.15	1.27	0.49
V	7 Months	0.37	1.22	1.67	0.96
B. Laboratory mixes, retainer samples—filed in screw-cap bottles					
WR	6 Months	0.33	—	0.42	0.05
TG	10 Months	0.55	1.08	0.70	0.02
AG-4	7 Months	0.45	1.19	0.49	0.02
AG-5	7 Months	0.33	1.20	0.38	0.01

[1] WE–1 and 2 were from a mill having their flour stream controlled to 0.40 to 0.42% ash for this self-rising flour. The samples were held by the mill since 1934 and 1933, and were supplied through the courtesy of W. E. Long & Co.

In order to obtain some information as to the inorganic constituents contained in the separated flour, the analyses shown in Table VI were performed by methods which need no elaboration, since they are in common use in analytical laboratories:

TABLE VI

INORGANIC CONSTITUENTS OF CCl_4 SEPARATED FLOUR

Sample	WE-1	WE-2	V	B-26[1]
pH of flour	5.76	5.78		
CO_2 as soda, per cent	0.01	0.03		
P_2O_5 (0.25% allowed for flour), per cent	0.12	0.21		
CaO, per cent	0.032	0.043		
NaCl (0.25% allowed for flour), per cent	0.31	0.92	1.15	0.62
Ash, per cent	0.84	1.30	1.67	0.97
Portion of ash (flour basis) as:				
NaCl, per cent	0.153	0.46	0.96	0.58
Total bases as Na_2O, per cent	0.08	0.21	—	—

[1] B–26 was a sample of flour mixed with salt, humidor-stored 48 hrs.

It is apparent that no soda or calcium salts were present in the separated flours. Some P_2O_5 appears to have been adsorbed by the flours during storage, possibly as phosphoric acid, but this is small in comparison to the amount of salt in the separated flour as well as in its ash. Furthermore, it is apparent that a variable amount of salt chloride is lost during the ashing process.

Discussion

Attempts were made to determine a factor by which true ash could be calculated from found ash in self-rising flours. Carbon tetrachloride-separated flour was ashed by various methods to retain, if possible, the chloride known to be present; ashing of the entire self-rising flour was tried; mechanical manipulations with the self-rising flour and the process of separating the flour have been given above; simple titrations on the separated-flour ash and on the self-rising flour ash were made. In all cases it was apparent to us that the heterogeneous reactions which occur in contaminated flour during the ashing process are such that no one or more end-products are formed which can be used as a criterion for calculation of the true ash content of the flour by means of a factor.

Storage of self-rising flours in containers impervious to moisture might result in a protection against humid atmospheric conditions, but this is outside the scope of the work reported here.

It was significant that no appreciable loss of leavening power of self-rising flour occurred when stored under very humid conditions.

Summary

The Gustafson method for the ash determination of all grades of phosphated flour is reliable when applied to flours either freshly mixed or after storage in a humid atmosphere. It is also reliable for freshly-mixed self-rising flours.

The method fails when applied to self-rising flours which have been subjected to moist storage conditions. The absorption of moisture by the salt was shown to result in either its adsorption on flour particles or, under severe conditions of storage, the formation of dried dough-balls both of which cause the salt to be carried by the flour, thus causing contamination of the flour layer during the separation of ingredients and resulting in fictitiously high ash analyses.

Moisture of materials before mixing a self-rising flour does not result in errors in flour ash when the flour has been properly stored.

The process of leavening deterioration and that of moisture absorption by salt apparently proceed independently in stored self-rising flour.

No modifications of the Gustafson method were devised which would overcome the effect of salt in the determination of the ash of self-rising flour.

FACTORS AFFECTING MALTOSE VALUES IN THE FERRICYANIDE METHOD FOR DIASTATIC ACTIVITY

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During the past year, the method for measuring diastatic activity (Blish and Sandstedt, 1933) has been studied to reduce certain factors disturbing to accuracy. A preliminary report (Davis, Leatherock, and Putnam, 1934) containing various suggestions calculated to reduce variability among check sample collaborators was sent members of the Pioneer Section. This material, because not generally available, has been verified by further study and embodied here. In the meantime, certain of the conclusions have been communicated to the A.O.A.C. by Associate Referee Blish (1934, 1935).

In the ferricyanide method for maltose, as in many other biochemical methods, there are some features not completely understood; and, since differences between collaborators usually are caused by small and seemingly insignificant changes in manipulation, " any deviation from established specifications is almost certain to cause error " (Blish and Sandstedt, 1933). In the final stage of the test, a maximum of only 17 mg. maltose is involved, which means that all errors as well as the sugar must be multiplied by at least 20 in making the conversion to the basis of 10 g. of flour. In the memorandum to the Pioneer Section (Davis et al., 1934), attention was drawn to the range in the standard deviations for maltose on the check sample reports as calculated by Davis. Data on ten of these samples have since been brought together and analyzed by Sandstedt (1934).

For the highest accuracy, the operations must be as continuous as possible. This is contrary to the original specifications which require that delays in manipulation be avoided until the samples have been " treated with ' acetic-acid reagent ' " after which, according to the suggestion, " The remaining operations can be done at the convenience of the technician." The effect of delay at this point is to cause high results. This has been carefully studied for several months under conditions imposed by room temperatures from 16° to 40° C.

In testing this, four 5 cc. portions were drawn from the filtrates and rapidly treated with ferricyanide reagent. Little time was lost by

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drawing one aliquot, then adding the ferricyanide reagent to it from an automatic pipet while a second aliquot was draining into another test tube, etc. Seldom as much as five minutes elapsed between the water thermostat and the boiling bath for each quadruplicate set from the same sample. Following treatment with acetic-acid reagent, alternates were titrated at once, while the others were held in covered flasks at room temperature. The effect of delaying titration of these mildly acid samples is shown in Tables I, II, III, IV, and V.

TABLE I

INCREASES IN MALTOSE DUE TO 15 MINUTES DELAY BETWEEN ADDITION OF ACETIC-ACID REAGENT AND TITRATION. (TESTS ON SAME SAMPLES MADE ON DIFFERENT DAYS. ROOM TEMPERATURES 25° TO 35° C.)

Sample number	Maltose value	Increase due to delay
	Mg.	*Mg.*
4017	181	2
4017	180	3
5750	235	1
5750	232	2
5772	303	7

TABLE II

EFFECT OF 30 MINUTES DELAY BETWEEN ACETIC-ACID REAGENT AND TITRATION. (TESTS MADE ON DIFFERENT DAYS DURING AUG. AND SEPT. 1934. ROOM TEMPERATURES 25° TO 40° C.)

Sample 4017		Sample 5750		Sample 5772	
Maltose value	Increase due to delay	Maltose value	Increase due to delay	Maltose value	Increase due to delay
Mg.	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*
180	3	231	5	312	8
178	4	232	5	310	11
178	3	233	3	313	9
179	4	234	2	307	10
185	3	236	7	303	4
181	1	234	3	304	6
182	3	230	4	304	7
183	1	231	4	304	9
183	4	231	4	304	5
184	2	228	7	—	—
176	6	233	1	$\bar{x}$ = 306.8	7.7
—	—	—	—	S_x = 3.9 mg.	
$\bar{x}$ = 180.8	3.1	$\bar{x}$ = 232.1	4.1	C. V. = 1.27%	
S_x = 2.85 mg.		S_x = 2.2 mg.			
C. V. = 1.58%		C. V. = 0.95%			

Delays between filtration and treatment with ferricyanide reagent were known to give higher results (presumably because of sucrose inversion (Blish and Sandstedt, 1933)), and were found to be a source

TABLE III

INDICATES INCREASES DUE TO ELAPSE OF ONE HOUR BETWEEN ACETIC-ACID REAGENT AND TITRATION. (TESTS ALL MADE ON SAME DAY. ROOM TEMPERATURE 30° TO 35° C.)

Sample number	Maltose value	Increase due to delay
	Mg.	*Mg.*
5777	327	8
5776	359	5
5778	328	5
4017	182	3
5779	316	10
5780	308	7
5781	320	8
5750	227	6
5782	302	9
4721	160	9

of error in addition to that produced by the delayed titration as shown above. In checking this, duplicate aliquots were rushed to the boiling bath. Following removal and cooling, both were treated with acetic-acid reagent. One was titrated immediately (Table IV,

TABLE IV

COMPARISON OF EFFECT OF DELAYS AT MORE THAN ONE POINT IN THE MANIPULATION. (TESTS ALL MADE ON SAME DAY. ROOM TEMPERATURES 27° TO 32° C.)

	First set—Prompt aliquotting		Second set—Delayed aliquotting	
	(1)	(2)	(3)	(4)
Sample number	Maltose value	Increase due to delayed titrating	Increase due to delayed aliquotting	Increase due to delayed titrating
	Mg.	*Mg.*	*Mg.*	*Mg.*
5761	294	11	5	16
5762	300	17	3	17
4017	180	12	3	9
5763	222	12	5	11
5764	284	16	1	17
5765	299	20	4	18
5766	293	15	0	16
5771	301	19	6	24
5772	307	13	8	14
Average increases:		15.0	3.9	15.8

column 1, Maltose value). The other was stored three hours at room temperature (27° to 32° C.), and when titrated, the nine samples gave an average increase of 15.0 mg. (column 2). In the meantime, the remaining filtrates had been covered and held at room temperature for an hour, after which duplicate aliquots were drawn and the procedure repeated. This one hour delay caused an average increase of

3.9 mg. (column 3), while the further three hour delay before titration produced an additional average increase of 15.8 mg. (column 4), comparable to that in column 2.

Since the foregoing determinations all had been made during hot weather, similar tests were undertaken during January, 1935, when the room was 16° to 18° C. These data are presented in Table V.

TABLE V

INCREASE IN MALTOSE DUE TO THREE HOUR DELAY BETWEEN ACETIC-ACID REAGENT AND TITRATION. (TESTS RUN ON SAME DAY. ROOM TEMPERATURE 16° TO 18° C.)

Sample number	Maltose value	Increase due to delay	Percent of increase
	Mg.	*Mg.*	*%*
5772	283	17	6.0
5772	288	14	4.9
5750	219	8	3.7
4017	177	7	3.8
4017	171	10	5.5
1616–3	134	5	3.6
1616–3	133	4	2.9

Blank determinations (in which either distilled water or a solution of buffer with acid and tungstate in the proper proportions was substituted for the 5 cc. of flour extract) were made with every set of tests. In certain instances there appeared to be a slight decrease in the ferricyanide available for reduction. Slight traces of reducing substances in the potassium iodide solution were found to be one cause of this difference. Any reduction of from 1 to 3 mg. from this source in the observed results was taken into consideration and only net increases reported. Repeated careful measurements confirm the belief that with pure chemicals, reduction of the ferricyanide reagent on standing (either before or after boiling and either with or without the acetic-acid reagent) will be negligible and cannot be held to account for any part of the increases in maltose noted as due to delay prior to titration of the samples after the acetic-acid reagent has been added.

Delays at any point in the procedure are not to be recommended since extracts from all flours do not behave toward the empirical nature of the test in exactly the same way. However, in some instances it may be valuable to know where delay may be inserted with least harm. It is believed that aliquots, alkaline with ferricyanide reagent, either before or after the boiling bath, may be stored for reasonable periods in a cold bath (15° C.) with little change. The data in Table VI show the results obtained with one group of samples so handled. In this set, three aliquots were used and treatment with ferricyanide was

TABLE VI

CHANGES DUE TO THREE-HOUR DELAYS AT POINTS WHERE SAMPLES ARE ALKALINE. (TESTS ALL MADE SAME DAY. ROOM TEMPERATURE 30° TO 32° C.)

Sample number	(1) Maltose value	(2) Change due to delay after boiling	(3) Change due to delay before boiling
	Mg.	*Mg.*	*Mg.*
5875	308	− 4	− 8
5876	146	5	− 2
5878	194	− 3	− 5
5879	309	0	0
5881	300	2	0
5772	297	4	1
5750	230	2	2
5772	304	− 1	− 2
1616–3	140	1	− 2

made as quickly as possible. The maltose values (column 1) were obtained by prompt titration, while the differences (column 2) were due to storing the duplicate sample for three hours before treatment with acetic-acid reagent and titration. The other differences (column 3) were obtained by storing the third aliquot (alkaline with ferricyanide reagent) three hours before boiling followed by prompt titration.

Only the purest reagents should be employed. Traces of moisture may be removed by drying potassium ferricyanide at not over 150° C. in an air or vacuum oven. Thiosulfate crystals should not be dried, and only clear crystals should be used. The normality of the thiosulfate may be readily verified between different solutions by using pure resublimed iodine, potassium bi-iodate, potassium iodate, or potassium bromate. Full directions for handling these (as recommended by the A.O.A.C. (1930)), may be found in Treadwell and Hall (1928). Only 0.05 *N* reducing solutions of any of these reagents should be used in standaridzing. It is probably safest to make blank determinations on each new set of reagents.

The addition of 3.8 g. of borax (Watson, 1932) to each liter of sodium thiosulfate solution will prevent bacterial deterioration and saves the necessity for redistilling all water for these solutions.

A stock buffer solution containing 164 g. of *anhydrous* sodium acetate and 120 cc. of glacial acetic acid per liter (25 cc. of which may be diluted to one liter of required strength) combine good keeping quality with convenience.

Higher results may occur in hot weather through slight losses of iodine (especially in blanks and in samples of low maltose) if samples are permitted to stand long after the addition of potassium iodide prior to titration. A thorough mixing following the potassium iodide and

before addition of starch solution will eliminate the slight tendency to form Prussian Blue.

If sand is washed with tap water or alkali and simply rinsed with distilled water before ignition, traces of alkaline carbonates may remain to interfere with the tests. These may be avoided (see Davis, Leatherock, and Putnam, 1934) by using a 5% acetic acid wash before the final rinse with distilled water. Best results are obtained when the formation of even the smallest particles of dough is prevented by liberal use of sand.

Sherwood and Bailey (1926) stored flours in the mill warehouse and in cold storage at from 7° to 10° C. They found no pronounced change in diastatic activity after one year, but noted an appreciable decrease at twenty-six months. Blish (1935) has noticed that flours apparently undergo a slight reduction in diastatic activity within a few weeks when stored at high room temperatures although no changes have been detected in flours stored at approximately 0° C. In the case of sample No. 5772, the average of nine determinations from Aug. 28 to Sept. 30, 1934 (Table II) was 306.8 mg. The average of 26 tests from Nov. 22, 1934 to Feb. 25, 1935, was 292.4 mg. The S_x of this latter being 3.6 mg., and the *C. V.* being 1.23%. The sample was stored at laboratory temperatures (37° to 16° C.) in glass stoppered bottles in which the moisture change was only from 12.9% to 12.6%. Incidentally the variability of these results is in agreement with that reported by Davis and Worley (1934) who found that, " The average standard error of a single determination was of the order 3.40 $\pm$ 0.34 mg. maltose per 10 g. of flour or 1.24% of the mean value of all flours studied."

When dealing with material of exceedingly high diastatic activity, such as flours from malted or sprouted wheat, or some durum flours, it may easily happen that even a 3 cc. aliquot of the clarified extract will contain more maltose than the specified quantity of ferricyanide can handle. In such cases, obviously, small errors, due to inaccuracies in measuring apparatus, temperature control, or solutions, are greatly magnified in the final calculation to milligrams of maltose per 10 g. of flour.

In instances of this kind it may be safer, and also the technician's preference, to avoid the necessity of using a 1 or 2 cc. aliquot by starting with a 1 or 2 g. sample of the flour instead of the 5 g. sample as specified and ordinarily used. If this is done it is highly imperative that the ratio of flour to buffer solution be kept essentially the same as though 5 g. had been used. Using 1 g. of flour, therefore, one must use only 10 cc. of buffer solution for the one hour extraction at 30° C., and with 2 g. of flour, 20 cc. of buffer solution. At the end of the digestion period, the suspension is diluted to 46 cc. with buffer solution, and

immediately clarified in the usual manner. Five cc. aliquots of the clarified extract may then be taken for the ferricyanide reduction.

If the ratio of one to ten is not maintained during the autolysis of the flour suspension, the results are affected as shown in Table VII, following.

TABLE VII

EFFECT OF VARYING THE RATIO OF FLOUR TO BUFFER SOLUTION. (TESTS ON SAME SAMPLES MADE ON DIFFERENT DAYS.)

Grams sample	5	5	5	5	5	1	2	3	4	1	1	1
Cc. buffer to digest	46	46	46	46	46	10	20	30	40	20	30	46
Cc. buffer added at one hour	(These five aliquots from same filtrate.)					36	26	16	6	26	16	0
Cc. aliquot tested	5	4	3	2	1	5	5	5	5	5	5	5
Cc buffer mixture added to aliquot	0	1	2	3	4	0	0	0	0	0	0	0
Flour samples	(Mg. maltose per 10 g. of flour.)											
B-2	312					320				280	260	230
Malt Flour-B					1030[1]	1060						950
Durum-B			500[1]			490						430
6388	264	270	271	266	283	278	264					192
6388	266					272	262	262	262	244	226	204
6388	265	268	272	270	278							
6388-M		352	360	365	364	365	363					270
6388-M		349				348	365	354	363	314	287	266
6388-M		352	356	363	361	360						
Malt Flour-A					1100	1101				1070	1042	970
Malt Flour-A					1104	1108						988

[1] Distilled water was used to make aliquots up to 5 cc. volume before addition of ferricyanide reagent. A mixture of buffer clarified with acid and tungstate was used with all other fractional aliquots.

The figures in Table VII show that diastatic activity tends definitely to diminish as the ratio of flour to buffer solution decreases. It is, therefore, necessary to keep this ratio constant (one to ten) during the one hour digestion, regardless of the quantity of flour used. The suspension may, however, be diluted with buffer solution immediately after autolysis, and just preceding clarification, in order to permit the use of 5 cc. for the ferricyanide reduction.

Whether to handle flours of extremely high diastatic power in this manner in preference to using 1 or 2 cc. aliquots of extracts prepared from a 5 g. sample is a matter for the individual technician to decide. Our experimental studies have not produced evidence convincingly

and decisively favoring either procedure, although the use of a reduced flour sample, thereby permitting the full-sized aliquot for ferricyanide reduction, is probably the safer procedure, especially where there is the slightest doubt as to the accuracy and precision of volumetric apparatus, temperature control, or standard solutions.

Since slight variations in the strength of the " 10% sulfuric acid reagent " have been known to affect results appreciably, it has seemed best (see Blish, 1935) to specify this in terms of normality—3.58 N $\pm$ 0.05 N. Thorough mixing of the acid with the flour extract before addition of the tungstate gives more rapidly filtering and clearer filtrates than otherwise would be obtained.

The concentration of the sulfuric acid in the filtrate affects the alkalinity of the sample during the reduction of the ferricyanide by the maltose. The usual practice is to use distilled water in making up to the 5 cc. volume any aliquots of less than that amount. It is probably a wiser practice to use a mixture of buffer to which acid and tungstate have been added in the proper proportions for making these fractional aliquots up to the usual volume. The use of such a mixture makes reasonably close results possible with even 1 and 2 cc. aliquots, whereas with water there is a tendency toward lower results as is shown in Table VIII, which follows.

TABLE VIII

EFFECT OF USING MIXTURE OF BUFFER, ACID, AND TUNGSTATE IN PROPER PROPORTIONS TO MAKE ALIQUOTS OF LESS THAN 5 CC. UP TO VOLUME.
(ALIQUOTS ALL RAPIDLY DRAWN FROM SAME FILTRATE FOR EACH SAMPLE.)

Cc. aliquot used	5	4	3	2	1
Cc. water or buffer-acid-tungstate mixture	0	1	2	3	4
Flour samples	(Mg. maltose per 10 g. of flour)				
6388 with water	265	266	261	250	240
6388 with mixture	265	268	272	270	278
6388 with mixture	264	270	271	266	283
6388-M with water		357	350	345	332
6388-M with mixture		353	356	363	361
6388-M with mixture		352	360	365	364

Since direct reading, rather than inverted scale burets, are probably more common for thiosulfate titrations, the following conversion table (calculated from the original table (Blish and Sandstedt, 1933)), may be convenient, especially in connection with high maltose flours.

Summary

For highest accuracy, it is essential that the manipulations be carried out with the least delay and with close attention to specifications. Samples treated with acetic acid reagent, as well as filtrates acid with sulfuric acid, produce higher results if allowed to stand. It is believed that aliquots alkaline with ferricyanide reagent may be stored cold for reasonable periods with but slight change.

Various practical suggestions are offered, covering standardization of thiosulfate, preservation of thiosulfate, convenience in handling buffer, a caution against iodine loss in hot weather, and preparation of sand for ignition.

Apparent reduction in diastatic activity at room temperatures is noted in contrast to no detectable changes at 0° C.

TABLE IX

MALTOSE CONVERSION TABLE INDICATES MILLIGRAMS OF MALTOSE PER 10 GRAMS OF FLOUR DIRECTLY FROM THIOSULPHATE BURET READING. (CALCULATED FROM ORIGINAL TABLE (BLISH AND SANDSTEDT, 1933).)

Cc. Thiosulfate solution used in titration	Milligrams of maltose basis weight of small samples or of cc. of fractional filtrates used				
	5	4	3	2	1
0.1	—	—	—	—	—
0.2	340	425	567	850	1700
0.3	330	413	550	825	1650
0.4	322	403	537	805	1610
0.5	317	396	528	792	1585
0.6	312	390	520	780	1560
0.7	308	385	513	770	1540
0.8	304	380	507	760	1520
0.9	300	375	500	750	1500
1.0	296	370	493	740	1480
1.1	292	365	487	730	1460
1.2	288	360	480	720	1440
1.3	284	355	473	710	1420
1.4	280	350	467	700	1400
1.5	277	346	462	691	1383
1.6	273	342	456	683	1367
1.7	270	338	450	675	1350
1.8	267	333	444	666	1333
1.9	263	329	439	658	1317
2.0	260	325	433	650	1300
2.1	257	321	428	641	1283
2.2	253	317	422	633	1267
2.3	250	312	417	625	1250
2.4	247	308	412	616	1233
2.5	243	304	406	608	1217
2.6	240	300	400	600	1200
2.7	237	296	394	591	1183
2.8	233	292	388	583	1167
2.9	230	287	383	575	1150
3.0	227	283	378	566	1133
3.1	223	279	372	558	1117

TABLE IX—(*Continued*)

Cc. Thiosulfate solution used in titration	Milligrams of maltose basis weight of small samples or of cc. of fractional filtrates used				
	5	4	3	2	1
3.2	220	275	366	550	1100
3.3	217	271	361	541	1083
3.4	213	267	356	533	1067
3.5	210	262	350	525	1050
3.6	207	258	344	516	1033
3.7	203	254	339	508	1017
3.8	200	250	333	500	1000
3.9	197	246	328	492	984
4.0	194	242	323	484	968
4.1	190	238	317	476	952
4.2	187	234	312	468	936
4.3	184	230	306	460	920
4.4	181	226	301	452	904
4.5	178	222	296	444	888
4.6	174	218	291	436	872
4.7	171	214	286	428	856
4.8	168	210	280	420	840
4.9	165	206	275	412	824
5.0	162	202	269	404	808
5.1	158	198	264	396	792
5.2	155	194	259	388	776
5.3	152	190	253	380	760
5.4	149	186	248	372	744
5.5	146	182	243	364	728
5.6	142	178	237	356	712
5.7	139	174	232	348	696
5.8	136	170	227	340	680
5.9	133	166	221	332	664
6.0	130	162	216	324	648
6.1	126	158	211	316	632
6.2	123	154	206	308	616
6.3	120	150	200	300	600
6.4	117	146	195	292	584
6.5	113	142	189	284	568
6.6	110	138	184	276	552
6.7	107	134	179	268	536
6.8	104	130	173	260	520
6.9	101	126	168	252	504
7.0	98	122	163	244	488

An alternative method for handling flours high in diastatic activity where less than 5 cc. aliquots normally would be necessary, is outlined together with the precautions to be observed.

The new specification of 3.58 $N \pm 0.05$ N for the " 10% sulfuric acid reagent " is mentioned.

For more accurate results with small aliquots, it is recommended that the normal alkalinity of the ferricyanide be maintained by using a mixture of buffer, acid, and tungstate, to make the volume up to 5 cc.

A table for direct calculation of results from buret readings is given to facilitate handling high maltose samples.

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REPORT OF THE COMMITTEE ON METHODS OF ANALYSIS

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Russell-Miller Milling Company, Minneapolis, Minnesota

(Read at the Annual Meeting, June 1935)

General Report

The work of the Methods Committee for the past year is presented in the various reports given by the committee members. Subjects which have been studied include the following: forced draft as an aid in moisture tests, the gassing power of flour, collaborative statistical studies on moisture methods for feeds, yeast variability, and the measurement of flour absorption.

E. G. Bayfield as chairman of the subcommittee on viscosity has continued the work on this subject. C. E. Mangels, the chairman of the subcommittee on the revision of the Books of Methods, has completed very successfully the considerable amount of work necessary for the revision and publication of "Cereal Laboratory Methods." This book will be an extremely valuable addition to the library of any cereal chemist.

Recommendations

It is recommended:

That methods for the measurement of the gassing power of flour be given further study.

That the vacuum-oven and air-oven (130° C. for 1 hour) methods be continued as the official moisture methods for wheat feeds as well as flour.

It is respectfully suggested to the incoming President that hereafter members of the Methods Committee be so chosen that each member will be responsible for collaborative work and a review of new developments in a particular field, such as proteins, diastatic activity and gassing power, testing of shortenings, leavening agents, etc.

Such an allocation of the work would be very helpful if another revision of "Cereal Laboratory Methods" is undertaken in the future, and would serve as well to inform cereal chemists of applicable or promising new methods both for control and research work.

A STUDY OF YEAST VARIABILITY AS MEASURED BY THE FERMENTOGRAPH [1]

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(Read at the Annual Meeting, June 1935)

Introduction

It is of great importance to ascertain the variability of different available brands of yeast and the uniformity of each individual brand from day to day in any laboratory making test bakes or measurements of the gassing power of flour.

Studies on the variability of yeast have been reported by Herman and Hart (1927), Clark (1929), Cook and Malloch (1930), Werner and Siedhoff (1929), Jørgensen (1931), Larmour and Brockington (1932), Weaver, Talbott, and Coleman (1933), and Sandstedt and Blish (1934).

Changes in the activity of yeast have been investigated and judged by the following methods: loaf volume as given by different baking formulas; evolution of carbon dioxide by the action of yeast on a buffered maltose solution; measurement of the amount of carbon dioxide developed in a dough, such as described by Bailey and Johnson (1924); and the manometric procedure of Blish, Sandstedt, and Astleford (1932) as it was modified by Sandstedt and Blish (1934).

Some of the earlier work indicated that various brands as well as the daily supply of the same brand of yeast showed marked variations in quality, while other investigations showed that these differences are not significant unless the yeast is used in large excess.

Experimental

The Fermentograph gives a measurement of the rate of gas production, corresponding periods of which can be correlated very well with the gas produced during the proofing period of the baking test. It is believed that this apparatus affords a more accurate and easily replicated means of measuring gassing power by any given formula than has been hitherto available. The formula used in this laboratory for testing yeast is different from that used for measuring the gassing power of flour. In the yeast-testing formula sufficient sugar is used in proportion to the

[1] Subcommittee report, 1934–35 Committee on Methods of Analysis.

yeast so that the amount of gas produced depends more on the yeast strength than on the diastatic activity of the flour. In these studies ingredients were used in the following amounts: yeast, 2%; sugar, 3%; and salt, 1%. The same flour, a short patent spring wheat flour, was used for all tests. Doughs were mixed in the Farinograph mixer with the water temperature control set at 30° C. The absorption used was such as to bring the maximum consistency of the dough (480 g.) to 500 Farinograph units and the mixer was stopped just as the dough reached its maximum consistency. A weighed piece of this dough was then placed in a rubber balloon, fastened to a metal gasket and suspended in a water bath at 30° C. (± 0.1° C.) on a chain hanging from the scale-head mechanism of the Fermentograph. The system was so adjusted that the recording pen was on the zero mark. When carbon dioxide is evolved in the dough, water is displaced as the balloon expands and a magnification of the relative gas production is recorded graphically. The balloon was removed from the apparatus at the end of each hour, the gas punched from the dough and the balloon then replaced in the gasket and the recording device set back to zero. This was continued over a total period of six hours. This method has been found to give good duplicate results,— ± 10 cc. being considered the maximum hourly variation.

Three different well-known brands of yeast were available for testing. The daily supply of each individual brand was tested over a 16-day period using the same flour for each determination. Results obtained from this series of experiments are given in Table I.

Each individual hour over the 16-day period and the total six-hour-gas-production for each yeast were averaged. The standard deviations were calculated and are shown in Table I. It will be observed that yeasts A and B are alike in type as shown by their hourly averages while yeast C acts more slowly. Yeast A, however, has a smaller standard deviation of each hour's gas production over the period covered than either yeast B or yeast C. Yeast A has the additional advantage in that the largest deviations occur in the first and second hours. In a bake the 3rd and 4th hour gas production is the most important, since the carbon dioxide formed during the first two hours is punched out. Yeast A shows much smaller deviations during the last four hours than the other two yeasts. Yeast C, which is a yeast of slower activity, shows its smallest deviations in the first two hours of gas production, and has unusually high deviations in the last four hours with a standard deviation of 42 cc. in the all important fourth hour. This variation would affect the gas development during the proofing period in the baking procedure. Yeast A shows a standard deviation of only 12.6 cc. for this

TABLE I

VARIABILITY OF THREE BRANDS OF YEAST

Cubic Centimeters of CO_2 Produced at Hourly Intervals

																	Average	Standard deviation
Yeast A																		
1st hour	420	405	390	400	400	420	375	355	430	410	400	380	365	365	340	380	390	24.6
2nd hour	585	590	570	590	590	590	570	535	630	590	600	590	570	555	545	570	580	22.1
3rd hour	600	600	605	600	600	605	585	580	650	610	600	620	580	575	575	585	598	18.5
4th hour	500	500	505	520	510	510	505	510	545	530	515	510	510	495	495	500	510	12.6
5th hour	410	410	415	400	415	410	410	415	455	435	425	425	425	420	415	415	419	12.2
6th hour	345	340	350	345	360	345	340	365	390	360	360	355	355	355	355	355	355	11.7
Total	2860	2845	2835	2855	2875	2880	2785	2760	3100	2935	2900	2880	2805	2765	2725	2805	2852	84.5
Yeast B																	Average	Standard deviation
1st hour	365	320	380	355	310	415	380	365	360	350	440	330	370	415	420	370	372	35.4
2nd hour	590	480	560	530	525	575	580	570	560	535	640	535	580	620	605	585	567	38.6
3rd hour	625	500	585	560	565	580	580	580	610	560	635	590	605	620	620	610	589	32.5
4th hour	570	435	520	515	520	500	505	520	525	505	545	525	550	540	545	550	523	29.5
5th hour	450	360	415	410	440	390	390	425	460	415	420	450	430	430	425	445	422	25.2
6th hour	365	305	340	340	360	320	315	340	380	345	330	370	340	335	330	355	342	19.7
Total	2965	2400	2800	2710	2720	2780	2750	2800	2895	2710	3010	2800	2875	2960	2945	2915	2815	143.1
Yeast C																	Average	Standard deviation
1st hour	300	275	300	320	305	305	305	280	285	270	315	300	265	300	240	280	290	20.3
2nd hour	470	455	510	545	495	500	490	475	475	450	510	480	455	480	425	465	480	27.7
3rd hour	475	470	530	545	510	520	490	470	475	450	505	470	460	470	450	475	485	28.1
4th hour	420	475	510	550	515	510	440	415	440	415	445	430	430	460	405	435	456	42.0
5th hour	360	430	470	485	480	475	355	350	380	350	375	335	355	410	365	375	397	51.6
6th hour	305	375	390	390	400	395	290	300	310	275	320	300	310	345	320	310	333	40.8
Total	2330	2480	2710	2835	2705	2705	2370	2290	2365	2210	2470	2315	2275	2465	2205	2340	2441	191.0

TABLE II

CHANGE IN GASSING POWER OF YEAST ON AGING

Cubic centimeters of CO_2 Produced at Hourly Intervals

Age of yeast in days	3	4	5	6	9	10	11	13	16	17	18	19	20	23	24	25	26	27	31	32
1st hour	435	425	435	440	440	430	400	420	410	425	410	430	430	415	390	390	360	370	365	360
2nd hour	605	590	595	615	620	610	585	610	600	600	610	630	640	630	605	600	570	585	590	585
3rd hour	590	600	600	600	610	620	600	605	610	610	630	640	640	640	630	610	600	610	610	610
4th hour	505	500	510	510	520	515	520	510	520	515	520	540	550	540	540	530	530	540	515	540
5th hour	410	415	410	405	420	425	420	410	425	425	430	430	445	440	440	430	430	420	445	450
6th hour	345	350	340	345	350	350	355	345	350	350	360	360	370	370	370	360	365	370	365	370
Total	2890	2880	2890	2915	2960	2950	2880	2900	2915	2925	2960	3030	3075	3035	2975	2920	2855	2895	2890	2915

Age of yeast in days	33	34	37	38	39	40	41	44	45	46	47	51	52	58	59	62	65	74
1st hour	370	350	320	310	290	310	235	235	240	265	250	275	240	170	170	185	75	20
2nd hour	595	585	540	550	520	550	480	465	470	500	480	510	470	390	390	420	250	130
3rd hour	615	620	580	590	565	585	530	520	525	530	530	570	525	470	485	495	380	230
4th hour	550	550	530	555	530	545	530	520	520	530	525	530	525	510	540	540	440	345
5th hour	460	455	465	470	450	460	460	450	450	450	450	465	455	480	510	490	470	385
6th hour	380	380	375	400	370	380	385	380	380	380	380	390	380	420	440	420	440	430
Total	2970	2940	2810	2875	2725	2830	2620	2570	2585	2655	2615	2740	2595	2440	2535	2550	2055	1540

interval while yeast B has a deviation of 29.5 cc. A study of Table I will show the unmistakable superiority of yeast A over yeasts B and C in the uniformity of supply from day to day.

Effect of Age on Yeast

The most uniform of the three yeast brands tested, yeast A, was selected for a series of experiments on the effect of age on the activity of yeast. Several pounds of yeast A were stored in an electric refrigerator at 40° F. and tested daily to determine the change in gas production. The yeast was three days old on the day of the first test—as fresh as it could possibly be obtained from the manufacturer. A measure of the gas produced at hourly intervals is given in Table II. The rate and six-hour total of gas production had not changed up to the 16th day at which time the yeast had started to darken a little about the edges. From the 18th to the 24th day there was an increase in the carbon dioxide produced each hour after the first hour, resulting in a higher total gas. The gas produced during the first hour began to show a loss on the 24th day and the 2nd and 3rd hours fell back to their original values, but the larger 4th, 5th, and 6th hour gas still kept the total gas production as high as on the original fresh yeast. On the 37th day the amount of gas produced in the 2nd hour was lower and from then on the total amount of gas evolved from the doughs very definitely decreased. During the period from the 37th to the 51st day, the results from day to day were not consistently in one direction—sometimes increasing a little, sometimes decreasing. This was due, no doubt, to non-uniformity within the yeast cake. By the 65th day the amounts of carbon dioxide produced during the first four hours had all dropped considerably and, although the 5th and 6th hourly values are higher than the original fresh sample showed at the corresponding periods, the total gas was lowered over 800 cc. On the 74th day the yeast was moldy. One test was conducted and the series discontinued.

The changes found in the rate of gas production agree very well with the results reported by Larmour and Brockington (1932). They found that the rate of carbon dioxide production in doughs is quite constant up to 26 days but that it increased and maintained a higher, although more irregular, level until an age of 56 days.

Conclusions

Two of the three yeasts tested, B and C, showed very large standard deviations in their hourly gas productions as well as in the total amount of gas produced in 6 hours. Such variations are significant since loaf volume and time required for proofing are dependent on the strength of

the yeast used. Yeast A, however, showed its largest standard deviations in the 1st and 2nd hours and in the later hours the deviations are not much larger than would be found in replicate tests on the same yeast sample.

The age of a yeast does not materially affect either the rate of gas production or total gas evolved until the 37th day. Hence, the brand of yeast and the uniformity of the daily supply have more effect on the gas production of doughs than the age of any individual yeast when properly stored at a low temperature.

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FORCED DRAFT AS AN AID IN AIR-OVEN MOISTURE TESTS [1]

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(Read at the Annual Meeting, June 1935)

Lanning [2] found that the 130° C. air-oven method for moisture tests was not seriously affected by small variations in time from the standard 60-minute procedure and that there could be considerable variation in the load of samples being dried. However, temperature variations were found to have a definite effect on the moisture results and different temperatures were found to exist at different levels in the oven.

Further study is here reported on other factors affecting the results by this procedure, and data are given to show that a forced-draft feature in the air oven can be utilized to give a considerable saving in time with no sacrifice of accuracy or precision.

Coleman and Dixon,[3] reporting on a special type of drying oven, obtained very satisfactory results with the time reduced to 15 minutes. The writer has numerous reports that cereal laboratories in this country and in Europe are satisfactorily using higher temperature than specified for the 130° C. air-oven procedure, combined with special draft conditions in the oven to obtain a definite saving in time for making moisture tests.

Experimental

The air oven used, and illustrated in Figure 1, was the same as described by Lanning [2] except that only two 16 mm. holes on each side and one 20 mm. hole in the bottom were provided for ventilation. The lower holes were even with the heating element and the upper holes were near the top of the drying compartment. One metal shelf with square perforations was placed equidistant between the side vent holes. The thermometer was kept even with the top of the moisture pans. The moisture pans were made of aluminum—50 mm. diameter, 12 mm. deep, with slip over covers, and in all cases the lids were left atilt on

[1] Subcommittee report, 1934–35 Committee on Methods of Analysis.

[2] Lanning, J. H. A study of the temperature changes in a small laboratory oven when drying flour by the 130° C. oven method. Cereal Chem. 12: 69–77 (1935).

[3] Coleman, D. A., and Dixon, H. B. A rapid moisture testing oven for cereal chemistry laboratories. Cereal Chem. 3: 419–426 (1926).

the pans during drying. The number of two-gram samples in the oven at one time is indicated in each table. There was considerable lag in temperature recovery after loading as noted by Lanning.

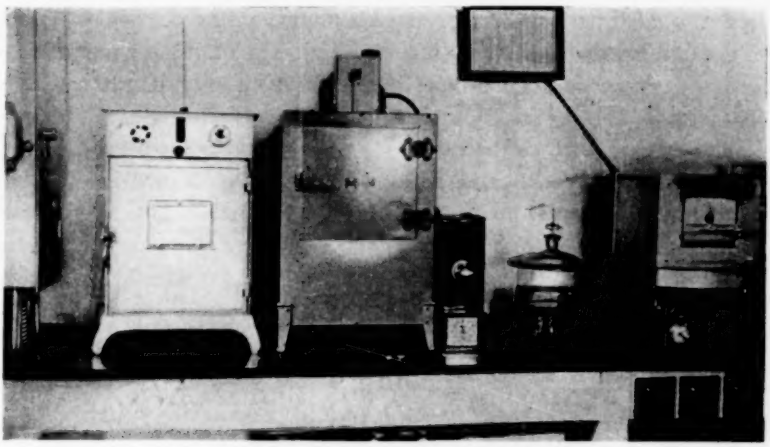

Fig. 1. Left: Air oven. Center: Forced-draft oven.

Three draft conditions were tried in this air oven. First, the regular ventilation channels were open; second, all ventilation openings were closed and the door taped shut; and third, a vacuum pump was attached to the top center of the drying chamber with the bottom vent open for air intake. In Table I there is no evidence that these conditions cause any significant differences in the results of the 130° C. one-hour, air-oven procedure. When the time was reduced to thirty minutes there was evidence that the draft produced by the vacuum pump gave more nearly accurate results and that the closed-draft condition gave definitely low results particularly when shorts and wheatmeal were tested. This would indicate that with a special draft condition in this oven the time factor possibly could be reduced.

TABLE I

AIR OVEN: EFFECT OF DIFFERENT VENTILATION CONDITIONS; 130° C. FOR 60 MINUTES. EACH REPORT AVERAGE OF 12 REPLICATES

Wheat product	Regular ventilation		Closed ventilation		Forced ventilation	
	$\bar{X}$	Sx	$\bar{X}$	Sx	$\bar{X}$	Sx
Flour No. 1a	13.36	.042	13.37	.040	13.39	.069
" " 1b	13.29	.045	13.26	.055	13.26	.064
" " 2	11.74	.044	11.80	.055	11.82	.070
Shorts No. 1	12.25	.117	12.25	.092	12.34	.141
" " 2	12.43	.077	12.42	.081	12.42	.105

The forced-draft oven, also shown in Fig. 1, was a commercial oven with drying compartment of the same size as the air oven described above. One air opening inlet of 5 cm. diameter, provided at the bottom, was baffled to heating elements in the space below the drying chamber. A second opening, 7 cm. diameter, at the top was connected with a small blower and damper to draw air out of the drying compartment. No provisions were made for special air circulation within the oven other than the forced outlet and intake with baffles. A 600 watt heating element was sufficient to keep the temperature up under all normal operating conditions. One shelf only, of ¼ inch mesh screen, was placed in the middle of the drying chamber. The thermometer bulb was placed even with the top of the pans. The recovery of temperature after loading took from one to two minutes. No definite measurements were made as to the quantity of air removed from the oven. The damper was opened sufficiently to insure a good air movement in the oven without sample loss and without taxing the capacity of the heating elements. Because thermostatic control was considered insufficiently accurate for this study the temperature was manually controlled within $\pm 2°$ C. of the temperatures used. The vertical air movement in this oven was possibly deflected by the tilted lids on the pans making a slight lateral air movement over the samples, thereby helping to remove the vapors immediately over the samples.

TABLE II

COMPARISON OF AIR-OVEN OFFICIAL METHOD WITH FORCED-DRAFT OVEN AT 130° C. AND REDUCED TIME. EACH REPORT AVERAGE OF 9 REPLICATES

Wheat product	Air oven—Official method		Forced-draft oven operated for					
			20 min.		30 min.		45 min.	
	$\bar{X}$	Sx	$\bar{X}$	Sx	$\bar{X}$	Sx	$\bar{X}$	Sx
Flour No. 1	13.26	.011	13.23	.022	13.24	.024	13.30	.037
" " 2	11.69	.027	11.24	.051	11.69	.011	11.65	.040
" " 3	11.76	.040	11.53	.110	11.75	.036	11.81	.053
" " 4	11.26	.039	11.19	.049				
Shorts No. 1	12.01	.066	11.76	.066	11.88	.058	11.95	.044
" " 2	12.50	.068	12.22	.160	12.31	.083	12.38	.095
" " 3	11.60	.100	11.36	.060				
Wheat No. 1	11.48	.040	11.37	.062				

As shown in Table II, using the forced-draft oven at 130° C. and reduced time, such samples as shorts, which give up their crude moisture less readily, cannot be made to give results strictly comparable with the 130° C., one-hour, air-oven procedure. Preliminary tests indicated that, at temperatures of 145° C. and 150° C., the moisture value was too high when sufficient time had elapsed to insure uniform results in

a set of twelve replicates. Also considerable darkening of the sample was observed in lower grade flours and feeds. However, 140° C. gave a very comparable yield at the earliest time in which anything like uniform results could be obtained between a set of twelve replicates in the forced-draft oven.

The data in Table III indicate that at 140° C. and 20 minutes the forced-draft oven results were comparable to the official air-oven procedure and that there was considerable leeway in the time during which the samples could be taken from the oven. This short time (20 minutes) procedure was selected and tested for reliability.

TABLE III

COMPARISON OF AIR-OVEN OFFICIAL METHOD WITH FORCED-DRAFT OVEN AT 140° C. AND REDUCED TIME. EACH REPORT AVERAGE OF 6 REPLICATES

Wheat product	Air oven—Official method	Forced-draft oven, 140° C., operated for 15 min.	20 min.	25 min.	30 min.	45 min.
Flour No. 1	13.07	13.02	13.10	13.14	—	13.18
" " 2	11.81	11.78	11.81	11.82	11.89	11.88
Shorts No. 1	11.96	11.84	12.00	12.00	12.06	12.12
" " 2	12.23	12.17	12.29	12.32	12.32	12.50
Wheat No. 1	9.79	9.61	9.81	9.77	9.82	9.95
Meal No. 2	12.23	11.75	12.21	12.28	12.28	12.29

Table IV gives the moisture yield and variability when twelve replicates were subjected to two procedures; namely, the official air-oven procedure and the 140° C., 20-minute, forced-draft oven procedure. Also the results are tabulated for the same samples treated at 140° C., 20 minutes in the air oven. The yield and standard error for each sample indicate that the 140° C., 20-minute, forced-draft treatment was as reliable as the standard air-oven procedure. The air-oven procedure with temperature raised to 140° C. and time reduced to 20 minutes gave a comparable yield but the variability in a set of replicates was high. When the lag in temperature rise after loading and the uneven heat distribution in the oven is considered, the latter procedure gave surprisingly close results.

When temperatures were increased to 150° C. and 160° C., the data in Table V indicate that high results can be expected and decomposition of the sample occurs. Shorts and wheat-meal samples do not withstand the 150° C. treatment for 15 minutes indicating that raising the temperature above 140° C. to reduce the drying time below 20 minutes is not a very likely procedure.

TABLE IV

COMPARISON OF MOISTURE METHODS. EACH REPORT AVERAGE OF 12 REPLICATES

Wheat product	Air oven—Official method		Forced-draft oven 140° C. (20 min.)		Air oven 140° C. (20 min.)	
	$\bar{X}$	Sx	X	Sx	$\bar{X}$	Sx
Flour No. 1 St	13.04	.037	13.07	.040	13.09	.052
" " 2 "	11.63	.029	11.67	.033	11.73	.074
" " 3 "	12.20	.029	12.18	.021	12.24	.041
" " 4 Cl	12.26	.043	12.25	.027	12.19	.056
" " 5 Pat	12.92	.030	12.95	.014	12.84	.057
Shorts No. 1	12.05	.057	11.97	.053	12.01	.050
" " 2	10.49	.084	10.49	.068	10.49	.088
" " 3	11.37	.096	11.35	.070	11.35	.106
Wheat No. 1	9.67	.064	9.64	.062	9.62	.079
Meal No. 2	11.99	.073	11.98	.059	11.91	.131

TABLE V

THE EFFECT OF HIGH TEMPERATURES ON FORCED-DRAFT OVEN DRYING. EACH REPORT AVERAGE OF 12 REPLICATES

Wheat product	20 min. 140° C.		20 min. 150° C.		20 min. 160° C.		15 min. 150° C.	
	$\bar{X}$	Sx	$\bar{X}$	Sx	$\bar{X}$	Sx	$\bar{X}$	Sx
Flour No. 1	11.13	.066	11.21	.055	11.37	.073	11.14	.041
" " 2	11.37	.035	11.43	.045	11.44	.030	11.28	.114
Shorts No. 1	11.59	.108	12.07	.178	12.91	.342	11.82	.136
Wheat No. 1	11.49	.063	11.63	.053	11.94	.064	11.63	.051

Discussion

It is obvious that definite air-movement conditions within ovens cannot be standardized to make a forced-draft procedure a satisfactory reference method for moisture testing between independent collaborators. Since the condition of ventilation has such little bearing on the reliability of the official air-oven procedure, its position is strengthened as a reference method. In this work the variability of results, particularly in the air oven, was caused principally by low results near the oven door, even when the door was taped shut. This could be due either to radiation through the door, lack of proper convection currents in this section of the oven, or to the sample recovering moisture immediately upon opening the door. The last cause appears to be the least probable.

The advantage of forced draft probably lies in the improved heat transfer and not so much in the rapid removal of a vapor laden condition in the vicinity of the samples being tested. The lag in temperature rise can be greatly reduced and the number of samples loaded into the oven at one time is less significant in affecting the results.

Summary

Different oven ventilation conditions were found to have very little effect on moisture results determined by the official air-oven procedure.

Samples dried 20 minutes in forced draft at 140° C. gave accurate and uniform results when compared with the official air-oven procedure for moisture.

A COLLABORATIVE STUDY OF THE MANOMETRIC DETERMINATION OF GASSING POWER [1]

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(Read at the Annual Meeting, June 1935)

Last year Sandstedt and Blish [2] described a simple manometric apparatus and method for determining the gassing power of flour. Their work was initiated primarily for the purpose of eliminating yeast variability as a factor in gassing-power studies. A series of determinations extending over a period of four months showed that yeast variability was not a factor when 3% of yeast was used, providing that the yeast was reasonably fresh and had been kept under proper refrigeration. The method gave reliable checks on the same flour over the entire period of time. Accordingly, it seemed advisable to subject the method to collaborative study among different laboratories.

Sandstedt [3] found that with flours of abnormally high diastatic activity it was necessary to use 5% of yeast instead of 3% in order to completely remove the excess sugar in a four-hour fermentation, that is, to give a true idea of the diastatic activity without extending the fermentation to six hours. For this reason it was thought best to also see how closely different laboratories would check using 5% of yeast.

Three flours of widely varying diastatic activities were chosen for collaborative trial. Flours A and B had been held in cold storage since the original work on this method. Flour A (diastatic activity 255, moisture 14.5%) was the flour used in the study of the variability of the method and the variability of yeast.[2] Flour B (diastatic activity 310, moisture 15.3%) was one of the flours used in the comparison of gassing power with diastatic activity.[3] Flour C (diastatic activity 150, moisture

[1] Subcommittee report, 1934–35 Committee on Methods of Analysis.

[2] Sandstedt, R. M., and Blish, M. J. Yeast variability and its control in flour gassing power tests. Cereal Chem. **11**: 368–383 (1934).

[3] Sandstedt, R. M. Diastatic activity in suspensions and doughs. Cereal Chem. **11**: 532–535 (1934).

9.8%) had not been used for gassing-power tests previous to this trial. These flours were sent to seven laboratories where the necessary aluminum pressuremeters are known to be in use, with the request that the gassing power be run on each flour by the method given in Cereal Chemistry, Vol. XI, page 372, using both 3% of yeast and 5% of yeast.

TABLE I

COLLABORATIVE GASSING-POWER RESULTS

Hours	3% Yeast									5% Yeast								
	Collaborator							April 24, 1934 [1]	Average	Collaborator							April 24, 1934 [1]	Average
	1	2	3	4	5	6	7			1	2	3	4	5	6	7		
	Millimeters of Mercury Flour A																	
1	89	80	87	86	80	94	80	88	86	104	101	107	107	102	103	104	114	105
2	219	203	207	218	197	231	202		211	277	263	276	278	268	278	285		275
3	351	348	346	339	342	360	342		347	379	379	373	384	368	367	377		374
4	402	414	405	404	400	410	395	400	404	419	422	415	424	413	421	419	412	418
5	442	451	440	437	435	442	438		441			444	455			447		449
6	462	476	468	461	463	467	456	456	464			469	480			471	459	470
	Flour B																	
1	81	76	80	81	77	88	76	82	80	96	93	99	102	97	108	109	110	102
2	203	194	194	210	192	224	193	205	202	270	249	257	268	260	275	288		267
3	339	333	330	344	334	362	329		337	415	412	411	414	404	411	415		412
4	438	445	435	446	439	449	423	450	441	467	476	467	477	464	464	466	469	469
5	492	494	486	497	492	490	475	500	491			503	511		483	499		499
6	518	525	518	527	524	520	504	533	521			530	538		522	524	529	529
	Flour C																	
1	81	83	89	90	82	91	83		86	96	102	105	108	95	115	111		105
2	189	180	188	198	182	206	193		191	197	206	210	212	205	213	203		207
3	212	225	226	229	222	226	215		222	209	227	227	230	217	225	214		221
4	220	238	241	242	232	241	230		235	217	234	240	241	229	238	226		232
5	234	249	251	252	246	252	239		247			249	251		244	235		245
6	239	258	260	261	255	261	249		255			257	259		252	242		253
	Diastatic Activity (Maltose Values)																	
Four A		258	254	256	249	259			255									
B		317	309	309	304	317			311									
C		150	147	150	145	149			148									

[1] Pressures obtained on flours A and B one year previous to this study.

Table I gives the hourly manometric readings in millimeters of mercury obtained by each collaborator on each flour, both with 3% and 5% of yeast. There is also a column headed " April 24, 1934 " which gives the pressures obtained on flours A and B one year previous to this collaborative check and also a column giving the averages of the determinations for each hour.

Collaborator 1 ran the determinations using 10 g. of flour on a 13.5% moisture basis. Accordingly, the pressures obtained by him were corrected to the original moisture basis in order to make them comparable to those obtained by the other collaborators. In the case of flour C with its low moisture content, it is questionable if this attempt to correct to the original moisture basis was entirely successful, since Collaborator 1 checked with the other collaborators on the other samples but was somewhat low on flour C.

The collaborative results are obviously very concordant and leave no doubt that this is a precise method, capable of giving values that can be duplicated at any time in any laboratory having the necessary pressuremeter equipment. For example: The variability among the results of the collaborators on flour A is practically the same as the variability reported by Sandstedt and Blish [2] over a period of four months with the same flour. The average of the pressures at the end of the fourth hour in the last year's report was 404.6 mm. compared to 404 mm. for the average of the collaborative results this year. The average of the pressures at the end of the sixth hour last year was 465.4 mm., while the average obtained by the collaborators is 464 mm. The notable agreement of results obtained in our own laboratory over a long period of time with results obtained in seven different laboratories a year later clearly indicates that the procedure fullfils all reasonable requirements of a standard method for gassing power.

Yeast variability obviously cannot be considered a serious factor either in this manometric method for measuring gassing power or in the standard A. A. C. C. baking procedure, providing, of course, that the yeast is reasonably fresh and has been kept under proper refrigeration.

Five per cent of yeast gives just as good checks as does 3% but the gain in time by the use of 5% of yeast on flours of normal diastatic activity is not enough to justify its preference over 3% of yeast, which moreover is the amount used in the standard A. A. C. C. baking test.

THE DETERMINATION OF MOISTURE IN FEEDS. A COMPARISON OF THREE MOISTURE METHODS [1]

ALAN E. TRELOAR [2] and B. SULLIVAN [3]

(Read at the Annual Meeting, June 1935)

The Methods Committee appointed for the year 1934–1935 was requested to make a collaborative survey of moisture methods for mill feeds.

Three methods are in common use among mill and feed control chemists for the determination of moisture in mill feeds. It was of importance to determine how closely these methods check and, if possible, to recommend one definite air-oven method. Grattan [4] has indicated the lack of uniformity in the moisture methods used for feed, pointing out the wide variation found in the time of drying, size of dishes, temperature, etc. It is convenient for most cereal laboratories to use the same method for feed as for flour (heating a 2-gram charge in an electric air oven at 130° C. for 1 hour). On the other hand, the A. O. A. C. has adopted as official a method for feeding stuffs (those not containing sugars) which consists in heating the sample in an electric air oven for 2 hours at 135° C. The vacuum-oven method as outlined in the Book of Methods of both the A. O. A. C. and the A. A. C. C. is regarded as the umpire method. The history of the development of the air-oven methods was very ably reviewed by R. K. Durham at the 1934 Convention.

Four wheat-feed samples, two of mill-run middlings and two of bran, were thoroughly stirred and 15 samples of each put up immediately. All samples of each feed were placed in ointment cans within the space of three to four minutes and sealed with Scotch masking tape immediately. Three persons put up the samples in order to avoid, as far as possible, any variation in the individual samples of the same feed. One sample of wheat middlings and one of bran were taken directly from the feed packers. The other two samples had been taken out one week previous and were spread on paper and exposed to the air in order to lower the moisture content before sampling. All four samples were milled from the same wheat mix. The samples were sent to collaborators immediately after sealing. In order to check any possible discrepancy in mois-

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[4] Gratten, G. E. Report on moisture in feeding stuffs. J. Assoc. Official Agr. Chem. 17: 178–179 (1934).

ture content due to sampling, the first and last samples of each feed put up were analyzed in the same laboratory. Duplicates between both samples checked as well as duplicates on the single samples. Collaborators were asked to report duplicate results on each feed in accordance with the detailed directions outlined below:

Each sample is to be tested by the following three methods. Dishes to be used are the conventional aluminum dishes, diameter about 55 mm., height about 15 mm., provided with an inverted slip-in cover. A 2-gram charge of the *unground* sample which has been well mixed with a spatula just previous to weighing is to be used for each test.

METHOD 1

Electric air oven at 130° C. Weigh accurately 2 g. of the well-mixed sample in a dish that has been dried previously at 130° C. (± 3°), cooled in a desiccator and weighed soon after attaining room temperature. Dry the dish, cover, and contents in the oven at 130° C. (± 3°) for 1 hour. Cover the dish while still in the oven, transfer to desiccator, and weigh soon after attaining room temperature. Report loss in weight as moisture.

TABLE I

RAW MOISTURE DATA, AVERAGES AND DIFFERENCES FOR SAMPLE I (BRAN)

Collaborator	Method 1	Average	Method 2	Average	Method 3	Average	Differences between averages		
							(1–2)	(3–2)	(3–1)
	%	%	%	%	%	%	%	%	%
1	9.55	9.525	9.55	9.555	10.25	10.410	−.030	.855	.885
	9.50		9.56		10.57				
2	9.10	9.050	9.27	9.240	9.44	9.395	−.190	.155	.345
	9.20		9.21		9.35				
3	9.24	9.283	9.31	9.293	9.94	10.067	−.010	.774	.784
	9.30		9.28		10.05				
	9.31		9.29		10.21				
4		9.560				9.630			.070
5	9.47	9.510	9.25	9.245	9.74	9.740	.265	.495	.230
	9.55		9.24		9.74				
6	9.50	9.500			9.50	9.500			.000
	9.50				9.50				
7	9.51	9.485			9.63	9.720			.235
	9.46				9.81				
8	9.49	9.525	9.52	9.495	9.79	9.860	.030	.365	.335
	9.56		9.47		9.93				
9			9.60	9.600					
			9.60						
10		9.550				9.550			.000
11	9.48	9.480			9.61	9.587			.107
	9.50				9.61				
	9.46				9.54				
12	9.44	9.455	9.68	9.685			−.230		
	9.47		9.69						
Av.		9.448		9.445		9.746	−.027	.529	.299

TABLE II

RAW MOISTURE DATA, AVERAGES AND DIFFERENCES FOR SAMPLE 2 (SHORTS)

Collaborator	Method 1	Average	Method 2	Average	Method 3	Average	Differences between averages		
							(1–2)	(3–2)	(3–1)
	%	%	%	%	%	%	%	%	%
1	9.87	10.015	9.73	9.725	10.01	10.590	.290	.865	.575
	10.16		9.72		10.98				
					10.33				
					11.05				
2	9.66	9.555	9.56	9.585	9.89	9.835	−.030	.250	.280
	9.45		9.61		9.78				
3	9.47	9.493	9.62	9.597	10.24	10.270	−.104	.673	.777
	9.49		9.60		10.34				
	9.52		9.57		10.23				
4		9.810				9.890			.080
5	9.76	9.765	9.61	9.570	9.94	9.925	.195	.355	.160
	9.77		9.53		9.91				
6	9.75	9.750			9.75	9.750			.000
	9.75				9.75				
7	9.74	9.710			10.15	10.085			.375
	9.68				10.02				
8	9.73	9.810	9.78	9.765	10.26	10.195	.045	.430	.385
	9.89		9.75		10.13				
9			9.85	9.800					
			9.75						
10		10.000				9.830			−.170
11	9.87	9.877			9.96	9.990			.113
	9.87				10.04				
	9.89				9.97				
12	9.57	9.545	9.70	9.740			−.195		
	9.52		9.78						
Av.		9.757		9.683		10.036	.034	.515	.258

METHOD 2

Vacuum-Oven. Weigh accurately 2 g. of the well-mixed sample in a covered dish that previously has been dried at 98°–100° C., cooled in a desiccator, and weighed soon after attaining room temperature. Loosen the cover (do not remove) and heat at 98°–100° C. for 5 hours in a partial vacuum having a pressure equivalent to 25 mm. or less of mercury. Admit dry air into the oven to bring to atmospheric pressure. Immediately tighten the cover on the dish, transfer to a desiccator, and weigh soon after room temperature is attained. Report loss in weight as moisture.

METHOD 3

Electric air oven at 135° C. Weigh accurately 2 g. of the well-mixed sample in a dish that has been dried previously at 135° C., cooled in a desiccator, and weighed soon after attaining room temperature. Dry dish, cover, and contents at 135° C. for 2 hours. Cover the dish while still in the oven, transfer to the desiccator, and weigh soon after attaining room temperature. Report loss in weight as moisture.

In sending in the results, kindly state the number of charges in the oven and the approximate time of cooling in the desiccator.

Results as reported by the various collaborators are given in Tables I, II, III, and IV.

TABLE III

RAW MOISTURE DATA, AVERAGES AND DIFFERENCES FOR SAMPLE 3 (BRAN)

Collaborator	Method 1	Average	Method 2	Average	Method 3	Average	Differences between averages		
							(1–2)	(3–2)	(3–1)
	%	%	%	%	%	%	%	%	%
1	14.58	14.590	14.27	14.200	14.55	14.685	.390	.485	.095
	14.60		14.13		14.82				
2	13.84	13.915	13.98	13.985	14.23	14.210	−.070	.225	.295
	13.99		13.99		14.19				
3	13.71	13.803	14.07	14.087	14.55	14.670	−.284	.583	.867
	13.86		14.14		14.66				
	13.84		14.05		14.80				
4		14.300				14.300			.000
5	14.06	14.060	13.88	13.890	14.30	14.350	.170	.460	.290
	14.06		13.90		14.40				
6	14.25	14.375			14.25	14.250			−.125
	14.50				14.25				
7	14.43	14.410			14.34	14.385			−.025
	14.39				14.43				
8	14.12	14.145	14.19	14.140	14.30	14.315	.005	.175	.170
	14.17		14.09		14.33				
9			14.20	14.225					
			14.25						
10		14.050				13.710			−.340
11	14.47	14.327			14.34	14.323			−.004
	14.36				14.35				
	14.15				14.28				
12	14.01	14.005	14.11	14.165			−.160		
	14.00		14.22						
Av.		14.180		14.099		14.320	.008	.386	.122

Statistical Study of Results

SYSTEMATIC DIFFERENCES BETWEEN YIELDS BY THE THREE METHODS

In arriving at an evaluation of the systematic differences between methods in any series such as the present one wherein certain collaborators failed to employ one or more methods, direct comparison of the grand averages for all collaborators should be avoided because of unequal representation of personal equations. The procedure of averaging available differences for individual collaborators largely avoids such pitfalls and is followed herein. Tables I to IV present the actual differences and Table V the pertinent statistics for the general comparison of methods. Fisher's t criterion was used to determine the significance of the average difference, $\overline{d}$, for each comparison as a deviation from the hypothetical value of zero.

TABLE IV

RAW MOISTURE DATA, AVERAGES, AND DIFFERENCES FOR SAMPLE 4 (SHORTS)

Collaborator	Method 1	Average	Method 2	Average	Method 3	Average	Differences between averages		
							(1–2)	(3–2)	(3–1)
	%	%	%	%	%	%	%	%	%
1	12.81	12.508	12.20	12.175	12.76	12.772	.333	.597	.264
	12.23		12.15		12.34				
	12.51				13.38				
	12.48				12.61				
2	12.07	11.965	12.08	12.010	12.24	12.220	−.045	.210	.255
	11.86		11.94		12.20				
3	11.89	11.913	12.17	12.147	12.78	12.927	−.234	.780	1.014
	11.91		12.15		12.96				
	11.94		12.12		13.04				
4		12.250				12.290			.040
5	12.14	12.155	11.80	11.890	12.31	12.355	.265	.465	.200
	12.17		11.98		12.40				
6	12.00	12.000			12.00	12.000			.000
	12.00				12.00				
7	12.26	12.290			12.46	12.370			.080
	12.32				12.28				
8	12.43	12.400	12.18	12.185	12.48	12.465	.215	.280	.065
	12.37		12.19		12.45				
9			12.20	12.25					
			12.30						
10		11.800				12.130			.330
11	12.40	12.307			12.37	12.347			.040
	12.28				12.39				
	12.24				12.28				
12	11.91	11.880	12.09	12.105			−.225		
	11.85		12.12						
Av.		12.133		12.109		12.388	.052	.466	.229

TABLE V

EVALUATION OF SYSTEMATIC DIFFERENCES BETWEEN METHODS
COMPARISON OF METHODS

	(1–2)	(3–2)	(3–1)
$\bar{d}$	−.029	+.417	+.202
no. of diffs.	20	16	36
P[1]	0.48	-10^{-4}	-10^{-4}

[1] Probability that a greater value of $\bar{d}$ might arise solely through chance factors.

One might deduce with confidence from these results that the employment of a temperature of 135° for two hours drives off more moisture than in the case of one hour's drying at 130° C., or 5 hours' drying in vacuo at 98°–100° C. There is no substantial evidence, however, of any real differentiation between the latter two methods—the commonly used one in cereal laboratories and the umpire method of the A. O. A. C.

Most moisture methods are based on the fact that on increasing the temperature the vapor pressure of water is raised. Each succeeding film of water adsorbed on colloidal material, however, has different properties (such as lower vapor pressure, a different dielectric constant, etc.) from ordinary water making the removal and estimation of the more tightly bound water increasingly difficult. One is limited in the temperature used to dry any organic material such as flour or feed because of the liability of these substances to destructive change at high temperatures. The impossibility of obtaining the true moisture content of cereal products by any simple procedure is apparent. It becomes necessary, therefore, to adopt some method as a standard which will yield consistent results from the point of view of the proportion of moisture driven off. If this proportion could be ascertained accurately, it would be a simple matter to convert the amount of moisture released by the method to the true moisture content. In the absence of accurate knowledge of these proportions for different moisture methods, the selection of a standard method of reference would seem essential. Such a method should be chosen preferably for consistency in replication and ease of application so that it would be employed as a method of general use.

Consistency of the Methods in Replicate Determinations

From the statistical point of view, perhaps the most important criterion of the adequacy of any method of measurement is its ability to yield consistent results under the general range of working conditions. That this range is fully covered in the present set of data is open to question. However, it affords as large a truly comparative series as it seemed feasible to accumulate when the study was initiated. The analysis of the series will provide preliminary bases for prognostication.

From a study of Tables I to IV, it will be observed that the collaborators' results differ widely in consistency. Some of the discrepancies are unreasonably large; others are so small as to raise the question of independence of the replicates. The need for caution in interpretation is clear.

The standard deviations for the errors by the three methods within all laboratories have been estimated by using Fisher's variance method. They are given in Table VI in three sections, the first including all results, the second including only the first two determinations of each collaborator, and the third excluding the results of collaborator number 1.

It will be observed that in every form of assembly of the data, the determinations using the vacuum oven (Method 2) show greater consistency than either of the other methods. This may be due in part to the possibility that the fewer number of collaborators who reported by

TABLE VI

ESTIMATED STANDARD DEVIATIONS FOR THE ERRORS OF REPLICATION

	Method	Sample 1	2	3	4	All samples
All analyses, all collaborators	1	.057	.097	.100	.121	.098
	2	.053	.048	.064	.060	.056
	3	.103	.291	.105	.237	.208
First two analyses, all collaborators	1	.041	.094	.083	.151	.100
	2	.023	.044	.059	.058	.048
	3	.104	.251	.081	.125	.155
All analyses, collaborators 2 to 12	1	.059	.079	.105	.085	.083
	2	.056	.051	.057	.063	.057
	3	.077	.062	.090	.068	.075

this method were well practised in the use of the special type of oven needed. Another reason may be that the air ovens used by certain collaborators were of inferior construction which made accurate temperature regulation difficult. On the other hand, it may reflect a true superiority of the vacuum method. Tests of the significance of the differences certainly lead to the judgment that the greater consistency by Method 2 is real and not ascribable to errors of sampling.

With respect to the relative merits of 1 hour at 130° C. (Method 1), and 2 hours at 135° C. (Method 3), it is difficult to draw conclusions of permanent value. This is due to the fact that including or rejecting the results of one collaborator makes a very substantial difference. If all results returned be included, Method 1 is certainly more consistent than Method 3. If all collaborators be considered with equal weight, the same conclusion stands but with weakened support. If collaborator 1 be dropped from consideration, no significant difference between the methods remain so far as consistency is concerned. One conclusion is clear—superiority in consistency of results by Method 3 is not in any way demonstrable from these investigations.

Conclusions

Moisture driven off from feeds by using an air oven for 2 hours at 135° C. exceeds by about 0.3% (absolute) the moisture evaporated by using an air oven for 1 hour at 130° C. or a vacuum oven for 5 hours at 98°–100° C. The latter two methods give essentially the same results.

Consistency of results in replicate analyses appears to be greater by the vacuum-oven method than by the air-oven methods mentioned above. There is no demonstrable gain in consistency through using the higher

temperature and longer time in the air oven so far as the data in hand are concerned. If the results of all collaborators reported herein are equally representative, the indications favor lessened consistency using the higher temperature and longer time.

THE USE OF THE FARINOGRAPH AS AN ACCURATE MEASURE OF ABSORPTION [1]

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(Read at the Annual Meeting, June 1935)

Introduction

One of the many important factors which influence the accuracy of the baking test is the amount of absorption used. The usual method of judging the optimum absorption by the feeling of the dough, either in a preliminary small dough, or in the dough during the baking procedure is dependent on the experience of the person handling the dough. Absorption also varies from one type of flour to another, depending on the quantity and quality of gluten as well as on development in mixing and other factors. Needless to say, such a trial and error method is too dependent on personal judgment and is not accurate or easily duplicated.

Several mechanical methods have been developed for determining the "consistency" or "plasticity" of dough and thereby the absorption property of flour. Among these are the Extensimeter (Chopin, 1921), the Penetrometer (Harrel, 1927), and a wattmeter measurement of the power required in mixing a dough in a motor-driven mixer (St. John and Bailey, 1929). Swanson and Working (1933) used the Sharples Super Centrifuge to obtain a relative absorption value for flours, and Fifield (1933) also experimented with this method. Although Fifield was able to get good duplicate results, he found the differences between the Super Centrifuge absorptions and the baker's absorptions ranged from 0.9% to 13.0%. Working (1934) experimenting further with the method found in two series of flour samples 65.6% and 70.3% of mechanically determined absorptions agreed within 0.5% with the baker's absorptions, but as many as 2.5% in one series and 5.3% in the other series varied over 3% from the absorptions used by the baker. Skovholt and Bailey (1932) used the Farinograph in determining the increase in absorption due to dry skim-milk.

A dependable absorption determination should give duplicate checks

[1] Subcommittee report, 1934–35 Committee on Methods of Analysis.

within 0.5% and should be accurate for the baker within less than 1%, for 1% or more error in absorption influences baking results.

It has been found in our laboratory that the Farinograph gives accurate, reliable, and easily replicated absorption results.

Experimental

Several flours, which had been handled many times in our test baking procedure and whose absorptions had been determined by trial and error method by an experienced baker, were used to establish the optimum consistency on the Farinograph. A Farinograph flour and water curve was made on each of these flours, using the absorption recommended by the baker. The amount of flour and water used was calculated to give 480 g. of flour and water dough. For example: the baker recommended 65% absorption at 13.5% moisture on a patent flour; the flour moisture was 12.5%, hence the flour would require 66.9% absorption. So, 287.6 g. of flour were placed in the mixing bowl of the Farinograph and 192.4 cc. of water were added from the burette as the mixer was running. With the temperature control for the mixer set at 30° C., all these flours gave approximately 580 Farinograph units as their maximum consistency. This consistency was, therefore, taken to be optimum for our particular baking formula and procedure. The absorption of any flour can then be determined by finding the proportion of flour and water which will develop a maximum consistency of 580 units with 480 g. of flour and water dough. Of course, any change in baking formula or procedure would change this optimum consistency, but a definite conversion factor can be employed since all absorption values are relative. Differences between duplicates on the same day and from day to day were always less than 0.5% in absorption. It was found that even extremes of moisture content in a flour had no effect on the absorption when calculated to the same moisture basis.

Experimental work has shown that flours with very weak glutens, whose Farinograph flour and water curves showed a rapid decrease in consistency after the maximum consistency had been reached, took the absorption at the time of mixing but became soft and sticky during fermentation. To prevent this difficulty 0.5 to 2.0% less absorption than was found by the procedure described above was used in the baking of such flours. The amount of absorption correction can be easily judged by one experienced in interpreting Farinograph flour and water curves, by the rate of drop in consistency in the curve. If a laboratory handled weak gluten flours regularly, the optimum consistency which they would establish for their routine work would be higher and this absorption correction would not be necessary.

Absorptions on hundreds of flours have been determined in this laboratory using 580 units for optimum consistency and used at the nearest 0.5% absorption by the baker. The absorptions as measured by the Farinograph curve, using corrections on flours with rapid decrease in consistency, have been highly satisfactory. Table I shows 63 flours,

TABLE I

COMPARATIVE WATER ABSORPTION VALUES

(All Results Calculated to 13.5% Moisture Basis)

Sample No.	Ash	Protein	Absorption		Loaf volume 100% basis	Gluten quality
			Farinograph at 580 units	Baker's		
	%	%	%	%		
1	0.44	9.30	55.6	54.0	64.7	Poor
2	.42	10.10	62.0	62.0	81.7	Good
3	.40	10.50	62.5	61.0	93.7	Fair
4	.41	10.70	60.5	60.5	92.7	Fair
5	.44	10.80	59.4	59.0	82.7	Fair
6	.44	10.80	61.2	61.0	95.3	Fair
7	.42	10.90	62.4	62.0	94.0	Fair
8	.45	11.10	61.6	61.5	90.0	Fair
9	.48	11.10	61.4	61.5	95.0	Fair
10	.48	11.10	62.0	61.0	93.7	Fair
11	.41	11.30	60.9	61.0	95.7	Fair
12	.50	11.30	62.6	61.5	92.7	Poor
13	.44	11.40	60.3	60.0	100.0	Fair
14	.47	11.40	62.9	63.0	92.7	Fair
15	.38	11.50	62.1	61.0	95.7	Fair
16	.44	11.50	62.7	62.5	90.3	Fair
17	.46	11.60	62.4	62.5	90.0	Fair
18	.53	11.70	60.3	60.5	96.0	Fair
19	.43	11.90	63.6	63.5	95.3	Fair
20	.44	11.90	62.7	62.5	99.3	Fair
21	.44	12.00	64.4	64.5	99.3	Good
22	.42	12.10	62.8	62.5	98.0	Fair
23	.37	12.30	64.0	64.0	97.3	Good
24	.42	12.30	62.7	62.5	97.7	Fair
25	.47	12.30	64.7	64.0	96.0	Fair
26	.41	12.40	63.6	63.5	101.3	Good
27	.40	12.60	63.5	63.5	100.3	Very good
28	.41	12.60	64.0	64.0	97.7	Good
29	.41	12.60	64.3	64.0	96.3	Very good
30	.41	12.60	66.0	66.0	99.0	Good
31	.42	12.60	64.2	64.0	99.3	Very good
32	.43	12.60	63.8	64.0	98.3	Fair

ranging in protein from 9.30% to 15.60% and in ash from 0.37% to 0.79%. The nature of these flours, their percentage extraction and the type of wheat from which they were milled were entirely unknown to the experimenter. The exact absorption found on the Farinograph and

TABLE I—(*Continued*)

Sample No.	Ash	Protein	Absorption		Loaf volume 100% basis	Gluten quality
			Farinograph at 580 units	Baker's		
	%	%	%	%		
33	.46	12.60	63.6	63.5	96.7	Good
34	.39	12.70	67.0	67.0	100.3	Very good
35	.42	12.70	64.7	64.5	99.7	Very good
36	.39	12.80	66.0	66.0	100.0	Very good
37	.43	12.90	63.8	63.5	98.7	Good
38	.43	12.90	63.8	64.0	96.7	Very good
39	.47	13.00	63.6	64.0	99.7	Very good
40	.42	13.10	64.7	64.5	101.3	Good
41	.43	13.10	63.7	64.0	101.0	Very good
42	.45	13.10	64.8	64.5	102.0	Good
43	.46	13.10	64.1	63.0	92.3	Fair
44	.46	13.10	64.8	64.5	101.0	Good
45	.46	13.10	67.0	67.0	100.0	Good
46	.48	13.10	64.1	64.0	103.0	Good
47	.49	13.10	64.6	64.5	98.0	Very good
48	.47	13.30	64.2	64.0	99.7	Very good
49	.38	13.40	65.1	65.0	107.0	Very good
50	.53	13.70	65.8	65.5	98.7	Good
51	.47	13.80	63.8	64.0	104.0	Very good
52	.52	14.10	66.8	66.5	101.0	Very good
53	.58	14.30	66.3	66.5	106.0	Very good
54	.45	14.60	65.7	65.0	101.0	Good, soft
55	.46	14.80	67.5	66.5	105.3	Good, soft
56	.64	14.80	67.0	66.5	98.0	Good, soft
57	.47	15.00	66.6	66.5	105.7	Very good
58	.79	15.00	67.4	67.0	99.0	Very good
59	.45	15.10	66.6	66.5	103.3	Very good
60	.51	15.20	67.6	67.5	100.0	Very good
61	.45	15.30	68.6	68.0	105.3	Good
62	.64	15.40	68.0	68.0	99.3	Very good
63	.70	15.60	70.0	70.0	98.3	Good

the absorption recommended to the baker are given. These absorptions were used and the loaf volumes obtained are recorded in Table I. There were 7 flours in this particular group which gave the type of curves requiring a decrease in absorption from 1.0% to 1.6%. Only in a very general way did the absorptions increase in direct order with the increasing percentage of protein and improving gluten quality.

It has also been found that absorptions on flour streams milled from the same wheat mix on the same day do not show a direct correlation between protein content or gluten quality and absorption value, although, of course, the general tendency is for high protein, good quality streams to carry high absorptions. In some cases flour streams with identical ash and protein content differed as much as 5% in absorption.

Summary

A method is described for determining flour absorptions on the Farinograph with a flour and water dough. The absorptions determined by this method have been found to be highly satisfactory in our test-baking procedure.

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REPORT OF THE SUBCOMMITTEE ON VISCOSITY [1]

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(Read at the Annual Meeting, June 1935)

About 3 years ago this subcommittee of the Methods of Analysis Committee was charged with the problem of evolving a viscosimetric procedure suitable for testing soft wheat flours. Following a survey of methods being used in various laboratories, the method outlined in Cereal Chemistry, vol. X, pp. 494–501, in which several increments of one normal lactic acid (the several increment method) are employed, was chosen as a tentative procedure. Collaborative testing with this method produced reasonable agreement between various collaborating laboratories.

Following the first year's work the subcommittee has largely engaged in the accumulation of data so that the limitations of the test and its field of probable usefulness could be determined. Reiman (1934) in a special study has outlined a satisfactory method for preparing the lactic acid. The several increment method has been applied to the constant weight (2 g.) of protein method (Alexander, 1932) by Reiman (1934) and by Bayfield (1934, 1935).

Due to increasing interest in the viscosity test some time ago, C. G. Harrel was appointed by the A. O. A. C. as Associate Referee on Standardization of the Viscosity Determination, and the A. O. A. C. has since adopted [3] the use of several increments of lactic acid and sufficient flour to give a constant weight of protein as a tentative method (LeClerc, 1935; A. O. A. C., 1935). Your A. A. C. C. viscosity subcommittee has actively collaborated in the A. O. A. C. work and it is hoped that eventually a uniform procedure or procedures may be adopted by both associations.

Since presenting last year's report and with the object of collecting further data on the usefulness and scope of the viscosity test, a joint project was undertaken by the author with V. Shiple, one of the subcommittee members. Complete details of the project are not yet available but a part of the data is presented in Table I. As only relative results were desired on these 100 samples the method for determining

[1] Subcommittee report, 1934–35 Committee on Methods of Analysis.
[2] Associate in Agronomy and Cereal Chemist.
[3] Apparently there is an error in the outlined procedure as given on page 77, Jour. A. O. A. C., Vol. 18.

the viscosity was not exactly the same as that employed by the subcommittee, differing in that the suspensions were mixed by mechanical means as outlined by Bayfield (1935). Each sample was tested by the constant weight of flour, as well as by the constant weight of protein, method.

TABLE I

THE EFFECT OF CROP ORIGIN UPON FLOUR VISCOSITY, 1933 CROP

(Average Results from Same 10 Varieties Grown at Each Location)

Location	Flour protein	Flour ash	Absorption	Loaf volume	
				Regular	Bromate
	%	%	%	*Cc.*	*Cc.*
	Locations with different soils but similar climate				
1	7.45	.353	57.3	545.3	520.4
2	8.76	.382	57.6	619.1	564.2
3	9.97	.418	58.4	629.1	605.1
4	10.99	.435	58.5	631.0	617.6
5	9.68	.438	58.2	616.9	606.7
	Locations with differing climatic conditions				
8	9.47	.435	59.1	612.5	605.0
9	8.59	.416	59.1	586.6	560.2
10	9.18	.445	59.1	587.2	572.2
11	9.55	.410	54.7	584.5	590.2
12	8.07	.408	53.0	562.8	525.8
Average	9.17	.414	57.5	597.5	576.7

Location	Viscosity—20 g. flour method					Viscosity—2 g. protein method					
	0 cc. acid	1 cc. acid	3 cc. acid	5 cc. acid	7 cc. acid	0 cc. acid	1 cc. acid	3 cc. acid	5 cc. acid	7 cc. acid	9 cc. acid
	°*MacM.*	°*MacM.*	°*MacM.*	°*MacM.*	°*MacM.*	°*MacM.*	°*MacM.*	°*MacM.*	°*MacM.*	°*MacM.*	°*MacM.*
	Locations with different soils but similar climate										
1	11.1	44.2	63.8	67.3	68.6	22.2	60.4	100.5	112.5	116.2	115.8
2	12.8	54.8	84.9	92.6	94.2	17.4	61.0	100.5	112.5	117.0	117.6
3	14.7	62.5	106.0	116.8	119.7	15.4	60.6	100.8	112.3	115.6	116.3
4	15.9	63.1	112.7	125.4	130.3	13.7	58.7	96.8	107.4	111.2	111.6
5	15.2	54.7	94.3	105.0	108.3	17.8	56.1	100.7	114.2	119.4	119.8
	Locations with differing climatic conditions										
8	12.3	44.4	78.1	86.9	90.1	13.7	45.2	83.2	93.2	96.6	97.1
9	12.0	38.6	66.0	73.6	75.5	16.8	41.7	79.3	91.2	95.1	95.4
10	14.4	45.2	79.2	87.8	91.1	17.1	46.5	86.3	97.0	101.6	102.4
11	14.3	63.7	101.6	110.4	113.0	16.0	61.9	101.1	113.8	116.5	116.6
12	9.9	35.9	56.8	62.8	65.1	18.0	38.4	74.0	85.2	90.4	91.7
Average	13.3	50.7	84.3	92.9	95.6	16.8	53.0	92.3	103.9	108.0	108.4

The data are being subjected to correlation analysis. At this time it may be stated that the constant weight of flour viscosity measurements gave practically as good a measure of flour strength as the bromated loaf volume procedure. Loaf volume and protein in wheat gave a correlation coefficient of + .7980; whereas viscosity (20 g. flour) and wheat protein were correlated to the extent of + .7740. The protein × viscosity (2 g. protein basis) coefficient equaled + .1700. These trends may be observed by examination of the data in Table I.

Table I is principally of interest as it illustrates the effect of crop origin upon flour viscosity. With the constant protein method it will be observed that with a uniform climate less variability in viscosity results was obtained than where the wheats were produced under more variable conditions. If the 2-gram protein method is a measure of protein quality, then this quality is influenced by growing conditions to some extent.

The 1934 Ohio winter wheat crop was unusually high in protein. Viscosity tests have been completed on part of the flours from samples of that crop and the results for several varieties of wheat grown under similar environmental conditions are presented in Table II.

TABLE II

VISCOSITY AND OTHER DATA FOR SEVERAL SOFT WHEAT VARIETIES, 1934 CROP

(Average for Four Samples of Each Variety)

Variety	Flour protein	Flour ash	Absorption	Loaf volume (bromate)	Viscosity in degrees MacMichael									
					20 g. flour method					2 g. protein method				
					0 cc. acid	1 cc. acid	3 cc. acid	5 cc. acid	7 cc. acid	0 cc. acid	1 cc. acid	3 cc. acid	5 cc. acid	7 cc. acid
	%	%	%	Cc.										
Trumbull	14.45	0.374	49.05	584.0	14.5	124.8	213.5	230.0	233.3	6.0	72.5	105.8	110.0	110.5
Fulhio	14.55	0.375	48.38	600.3	14.0	122.5	205.8	221.8	224.3	5.5	68.5	98.5	103.0	104.5
TN 1006	15.30	0.372	48.18	652.0	14.8	119.3	216.3	235.0	236.8	5.3	68.5	99.8	104.5	105.5
Purdue No. 1	13.58	0.424	48.35	651.0	12.0	80.8	165.5	185.3	191.8	6.0	63.5	102.5	110.5	112.8
Michikof	16.80	0.420	52.63	718.3	20.8	161.5	374.3	437.3	458.3	5.5	75.8	126.8	139.3	143.8
TN 1029	14.28	0.387	46.58	570.3	18.0	87.3	152.0	168.8	171.8	6.8	49.8	73.8	78.3	79.3
Dawson	13.05	0.375	45.90	606.3	9.0	66.5	122.5	134.5	136.8	5.0	44.5	73.0	79.3	80.8
Minhardi	13.48	0.383	47.65	575.0	12.5	94.5	176.8	196.0	201.3	6.3	60.3	95.8	104.5	106.0

The high quantities of protein show up in these samples in the constant weight of flour method (20 g. flour). These data indicate that with very strong samples of flour (see Michikof) the strain point of the No. 30 wire specified in the procedure (Cereal Chem. **10**: 494–501) may be exceeded. However, it is not anticipated that flours of such strength will normally be encountered in the trade. Thus, a 12.80%

protein, 0.39% ash, all hard red spring commercial flour (unbleached) gave a viscosity of only 281° MacM. (20 g. flour) when subjected to the same procedure as were the Michikof flour samples. However, it may happen that occasionally some flours will prove too strong to be tested according to the method used by the subcommittee. Part of the varieties given in Table II were grown in 1933 (Bayfield, 1935) as well as in 1934 and were subjected to similar viscosity procedures. Comparisons between the crops produced in the two seasons indicated much larger differences in the constant flour viscosity data than in the constant protein viscosity data.

Just before preparing this report the chairman polled various members of the subcommittee in order to obtain a representative viewpoint of the group with respect to viscosity determinations at the present time. A majority of the subcommittee members favor:

Use of the several increment method with (*a*) constant weight of flour (20 g. on a 15% moisture basis), and (*b*) constant weight of protein (sufficient flour to equal 2 g. protein). The constant weight of flour method is to be used in order to give a picture of flour characteristics "as is"; whereas the constant weight of protein method was to be used as a measure of protein quality.

The method of making the suspension and performing the test as outlined in Cereal Chemistry **10**: 494–501 is proving satisfactory for soft wheat flours in routine control work.

The question of the advisability of using a one-hour digestion period at 30° C. is left open for further investigation before final action is taken.

No action appears advisable at present regarding the method to be employed in standardizing the MacMichael viscosimeter. This problem is being handled as a joint project with the A. O. A. C.

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THE DISTRIBUTION OF NITROGEN IN THE SEED OF ZEA MAYS AT DIFFERENT STAGES OF MATURITY

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Introduction

A survey of the literature indicates that very little is known concerning the proteins of the immature seed of any plant species and their relationship to the simpler nitrogenous compounds of the seed and to the proteins of the mature seed.

Woodman and Engledow (1924) have made peptization studies on the nitrogenous constituents of wheat at nine different stages of maturity. Their results show an increase in the gliadin and glutenin fractions accompanied by a decrease in the globulin and non-protein fractions as the wheat approaches maturity.

Sharp (1926) has made a somewhat similar study of the composition of wheat and mill products from frozen and unfrozen wheat.

The object of the present study is to determine the relative proportions of the various proteins of the corn kernel at different stages in its development and, if possible, to show some relationship between the formation of the proteins and the changes which occur in the non-protein nitrogen fraction. The first sample in the series was taken at as immature a stage as was practicable to collect, in the belief that the most rapid changes in composition occur in the earliest stages of growth. It was originally intended also, to isolate and analyze the proteins and simpler nitrogenous compounds at the different stages in hopes of obtaining a more accurate picture of the actual synthesis of protein within the seed. Unfortunately, however, circumstances have made it impossible to complete this work at the present time; therefore, the data herein presented should be considered merely as a preliminary report.

Materials and Methods

Fresh samples of Russler's white dent field corn were collected during the summer of 1932 from the fields of the Minnesota Agricultural Experiment Station at University Farm, St. Paul, Minnesota. These

samples were collected at four different stages of maturity, great care being taken that all ears in each picking were as nearly uniform as possible.

The four stages of maturity selected may be briefly described as follows:

Sample A—Very young, silk mostly green, kernels about one-fifth mature size.

Sample B—Silk brown, kernels nearly full grown, but still very "milky."

Sample C—Kernels starting to dent, practically no "milk," husks starting to turn brown.

Sample D—Ripe corn.

Immediately after picking, the corn was cut from the ears by hand, a small sample saved for moisture determination, and the balance ground and air-dried in thin layers at 40° C. with the aid of electric fans.

The dried samples were extracted with petroleum ether for 24 hours and total nitrogen determinations made on the ether-extracted material by the Kjeldahl method.

TABLE I

MOISTURE CONTENT OF FRESHLY PICKED AND OF AIR-DRIED SAMPLES AND TOTAL NITROGEN CONTENT OF DRIED ETHER-EXTRACTED SAMPLES

Sample	Moisture		N
	Freshly picked	Air-dried	Dry basis
	%	%	%
A	88.41	13.95	3.89
B	77.62	10.27	2.22
C	55.64	10.59	2.11
D	21.36	10.62	2.10

The nitrogenous constituents of these four ether-extracted samples were fractionated by successive extractions with water, molar-sodium-chloride solution, hot 80% ethyl alcohol, and 0.2% potassium hydroxide solution. One-gram portions of each sample were shaken for 1 hour with each of the above solutions, filtered and washed with three successive 50 cc. portions of the solution. The samples were air-dried after each extraction. In the case of the sodium chloride extraction, the salt was completely washed out with water before drying the sample. The filtrate and washings from each extraction were combined and the total nitrogen determined by the Kjeldahl method.

THE WATER "SOLUBLE" FRACTION. The nitrogenous compounds which were extracted by water were further separated into the following fractions:

1. *Globulin Peptized by the Inorganic Salts Occurring in the Corn.* This fraction was removed by dialysis of the water extracts in cellophane bags against distilled water. The water was changed at frequent intervals until no more nitrogen appeared in the dialysate. The globulin fraction precipitated on the inner surfaces of the cellophane bags.

2. *Proteose or Peptone.* The filtrate from the globulin precipitates contained an appreciable amount of non-dialyzable nitrogen. Since no precipitates were formed on boiling these filtrates, the absence of albumins was demonstrated. Accordingly this fraction is tentatively classified as a proteose or peptone.

3. *Non-Protein Nitrogen.* The dialysate from the globulin and proteose fractions contained any amino acids, peptides, and other relatively low molecular weight non-protein nitrogenous compounds present in the original samples. A more detailed study of this fraction was made by determining the amino nitrogen before and after hydrolysis, and by the partial separation of the hydrolytic products by the method of Van Slyke (1911, 1915).

The "Globulin" Fraction. In the present study the globulin will be defined as that fraction of the protein which may be peptized by molar sodium chloride solution, but not by water. The globulin fraction noted in the section above would without doubt have been included in the present fraction had it not been peptized by the inorganic constituents of the corn in water solution. No attempt has been made to determine any other differences which may exist between these two globulin fractions.

The globulin fraction of most biological products is at best, only an empirical fraction since it has been shown by Gortner, Hoffman, and Sinclair (1928, 1928a) that different salts or different concentrations of the same salt will in general peptize different quantities of protein from any given source.

The Prolamine. The prolamines are the characteristic proteins of the cereal grains. Zein, the prolamine of corn, is the most abundant protein in the mature corn kernel and is readily peptized by hot 80% ethyl alcohol.

The Glutelin. This fraction is not peptized by neutral solvents, but is readily peptized by dilute acids or alkalies. The glutelin of corn is known as Zeinin. This protein was first isolated by Osborne and Clapp (1907) and has been studied in greater detail by Larmour (1927).

Nitrogen Not Peptized. No attempt has been made to separate or study the nitrogenous substances which were not peptized by water, molar sodium chloride, hot 80% ethanol, or 0.2% potassium hydroxide.

Part of this fraction undoubtedly consists of seed coat proteins about which little is known since they are very difficult to separate from the insoluble carbohydrate material with which they are associated.

Results and Discussion

The percentages of the total nitrogen content of the four samples represented by the various fractions discussed above are shown in Table II and graphically in Figure 1.

TABLE II

NITROGEN DISTRIBUTION OF THE SEED OF *Zea Mays* IN FOUR SUCCESSIVE STAGES OF DEVELOPMENT. PERCENTAGES BASED ON TOTAL NITROGEN

Sample	Water-soluble non-protein nitrogen	Proteose or peptone nitrogen	Globulin nitrogen	Prolamine nitrogen	Glutelin nitrogen	Nitrogen not peptized
	%	%	%	%	%	%
A	41.10	1.47	7.71	2.78	12.96	33.98
B	31.15	2.23	6.58	13.45	18.20	28.39
C	14.87	1.30	8.42	30.16	16.98	28.27
D	4.57	1.71	7.82	41.97	16.92	27.01

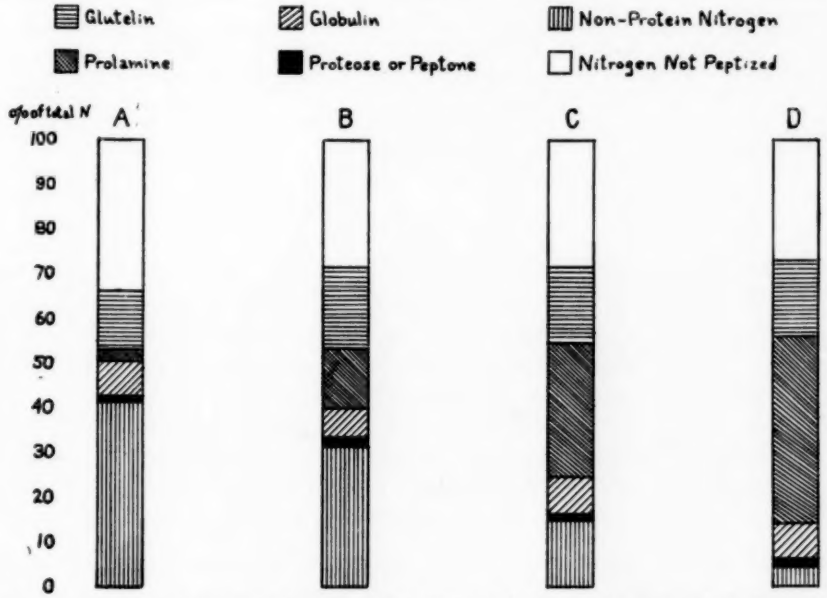

Fig. 1. Nitrogen distribution of the seed of *Zea Mays* in four successive stages of development. *A*, very immature; *B* and *C*, intermediate stages; *D*, ripe seed.

The prolamine nitrogen increases progressively from 2.8% of the total nitrogen in Sample A to 42% in Sample D. At the same time the

water-soluble non-protein nitrogen decreases from 41.1% in Sample A to 4.6% in Sample D. The ratios of the proteose or peptone nitrogen, globulin nitrogen, and glutelin nitrogen to the total nitrogen remain relatively constant throughout the series.

These results indicate that the globulin and glutelin are being synthesized at relatively constant rates throughout the growth period of the corn kernel, while the Zein, on the other hand, is present in only very small quantities in the early stages and is synthesized at a very rapid rate as the corn approaches maturity. This rapid increase in the ratio of Zein nitrogen to total nitrogen is almost exactly paralleled by the rapid decrease in water-soluble non-protein nitrogen, indicating that the water-soluble nitrogenous compounds are probably largely utilized in the synthesis of the Zein.

The amino nitrogen content of the water-soluble non-protein nitrogen fractions was determined with the Van Slyke apparatus. Duplicate aliquots were then hydrolyzed by boiling with 20% hydrochloric acid for 24 hours at atmospheric pressure and subjected to a partial Van Slyke analysis. The results obtained are shown in Table III.

TABLE III

ANALYSIS OF THE WATER-SOLUBLE NON-PROTEIN NITROGEN FRACTIONS OF CORN SAMPLES AT DIFFERENT STAGES OF MATURITY

Results are expressed in percentages of total water-soluble non-protein nitrogen.

	Sample			
	A	B	C	D
	%	%	%	%
Amino nitrogen before hydrolysis	40.94	43.07	28.28	18.99
Ammonia nitrogen	18.18	15.03	15.16	15.31
Humin nitrogen	8.26	9.14	9.05	15.88
Amino nitrogen after hydrolysis	60.79	57.28	57.73	43.27
Non-amino nitrogen (by difference)	13.34	21.02	20.12	25.18
Basic nitrogen	13.90	16.63	18.41	21.55
(*a*) Basic amino nitrogen (by difference)	5.19	1.03	0.06	1.00
(*b*) Basic non-amino nitrogen (by difference)	10.32	15.99	16.61	21.74
Non-basic nitrogen	58.62	61.28	61.18	45.71
(*a*) Non-basic amino nitrogen (determined)	55.60	56.25	57.67	42.27
(*b*) Non-basic non-amino nitrogen (by difference)	3.02	5.03	3.51	3.44

There is a rapid decrease in free amino nitrogen as the corn approaches maturity. The decrease in the amino nitrogen after hydrolysis is much less marked as indicated by the following ratios of free amino nitrogen to total amino nitrogen after hydrolysis: A, 0.673; B, 0.752; C. 0.490; D, 0.439. This indicates either that a condensation of the simpler amino compounds to higher molecular weight non-protein sub-

stances (probably polypeptides) has taken place, or that the simpler compounds have been utilized directly in the synthesis of protein at a more rapid rate than the more complex compounds. The most logical explanation is that free amino acids are first formed and that these undergo progressive condensation into protein during the maturing of the seed. The water-soluble nitrogenous compounds in the mature corn are then largely composed of the residual polypeptides and possibly free amino acids which were " left over " from the protein synthesis.

The relatively constant proportion of ammonia nitrogen is roughly a measure of the amido compounds, probably chiefly asparagine, glutamine, or both. A small part of this ammonia is probably derived from the deamination of amino compounds during the acid hydrolysis.

The relatively high humin fraction is in each case unquestionably due to the presence of water-soluble carbohydrates which furnish the potential aldehyde for the tryptophane-aldehyde reaction resulting in the formation of humin.

The non-amino nitrogen (after hydrolysis) falls chiefly in the basic fraction as would be expected, and increases in proportion as the corn approaches maturity. The exact nature of these basic nitrogenous compounds has not been determined, but from the ratios of amino to non-amino nitrogen it is clear that basic amino acids may occur in appreciable quantity in this fraction only in the case of the very immature corn (Sample A). The very low amino nitrogen content of the basic fractions of the three more mature samples indicates that the chief constituents must be organic nitrogenous bases containing no aliphatic primary amino groups.

Conclusions

The globulin and glutelin of the corn kernel appear to be synthesized at a relatively uniform rate throughout the growth period.

Zein is nearly absent in the very immature corn kernel but is synthesized at a very rapid rate as the corn approaches maturity.

The rapid increase in the ratio of Zein nitrogen to total nitrogen is almost exactly paralleled by the decrease in water-soluble non-protein nitrogen.

The asparagine, glutamine, or other amide content of the non-protein nitrogen fraction remains relatively constant throughout the growth period of the corn kernel.

The simpler amino compounds undergo rapid condensation as the corn approaches maturity. This is probably chiefly a condensation of amino acids into polypeptides.

The basic nitrogen of the water-soluble non-protein nitrogen fraction increases as the corn approaches maturity. At the same time the basic

amino nitrogen falls to a very low value indicating that the water-soluble basic nitrogen compounds in mature corn consist chiefly of organic nitrogenous bases which do not yield primary aliphatic amino compounds on hydrolysis.

The presence of a proteose or peptone in corn is indicated.

Acknowledgment

The writer wishes to express his appreciation to Prof. R. A. Gortner, Chief of the Division of Agricultural Biochemistry at the University of Minnesota for the use of the supplies and equipment of that division in the carrying out of this work, and also for his sincere interest and helpful suggestions.

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MODIFICATION OF THE SOXHLET EXTRACTOR

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Bull [1, 2] finds that in fat extraction by means of the Soxhlet apparatus the ether passes through the filter paper in preference to

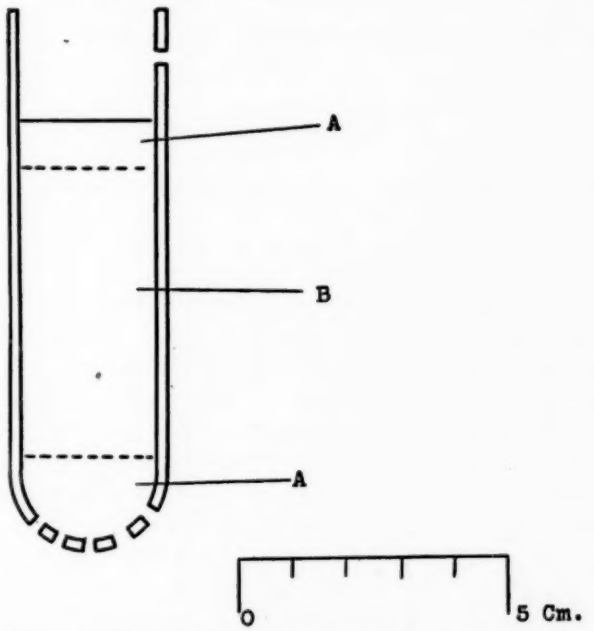

Fig. 1. Constructional details of a glass thimble adapted for weighing extracted residues. (*A*) represents cotton, (*B*) material to be extracted.

percolating the substance. To remedy this, it is recommended to fix inside the thimble a cylinder of sized writing paper.

The writer has experienced this difficulty in petroleum ether extractions. To obviate the condition, it is suggested that a glass tube, open at both ends and of such a diameter as to fit closely in the thimble, be

[1] Bull, H. Fat extraction by means of the Soxhlet apparatus. Tid. Kemi. Farm. Terapi. **9**: 321–325 (1912); Chem. Abst. **7**: 2442 (1913).
[2] Lewkowitsch, J. Chemical Technology and Analysis of Oils, Fats and Waxes. Sixth Edition **1**: 291 (1921).

used. The tube should extend from the bottom to a short distance over the top of the thimble.

To avoid the need for Fruhling's admirable, but expensive, modified form of the Soxhlet extractor [3] when it is desired to weigh the material before and after extraction, the writer uses a cut-off test tube as a thimble. A number of holes are blown in the rounded end of the tube, which is used in the same manner as a thimble. Figure 1 shows such a tube adapted for extraction purposes. Before inserting the material to be extracted, a layer of cotton is placed in the bottom of the tube. A plug of cotton wool is placed on top of the material after the tube has been filled. To facilitate weighing, a hole is blown in the wall of the tube near the top to admit a wire hook during the operation of weighing.

REPORT OF THE COMMITTEE ON TESTING BISCUIT AND CRACKER FLOURS

R. M. BOHN, *Chairman*

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(Read at the Annual Meeting, June 1935)

In the first report of this committee [1] there was every indication that a combination of the baking and viscosity test results in the hands of one familiar with biscuit and cracker flour requirements, will accurately classify soft wheat flours into cracker sponge, cracker dough, and cooky types. In order to check these findings on more than one year's crop, it was decided to repeat the work this year. The methods used in examining the flours reported here were identical with those given in the previous report except that the viscosimeter speed was 12 r.p.m., instead of 14 r.p.m., since 12 r.p.m. seems to be in more common use at present. Reference should be made to the previous report for details of these methods. The analytical findings of the collaborators are shown in Tables I, II, III, IV, and V.

In order that there be variety in the flours selected, George Garnatz of the committee was asked to send out the samples to the committee members under code number. The members were asked to examine the flours as before and classify them for biscuit and cracker use. In studying the results for each flour, it should be remembered that the committee members were not aware of the identity of the flours or their utility as determined by bakeshop use at the time they made their reports.

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[3] Ibid., p. 292.

[1] Bohn, R. M. Report of the committee on testing biscuit and cracker flours. Cereal Chem. 11: 661–668 (1934).

TABLE I

BAKING AND VISCOSITY TESTS ON FLOUR A-2

A Pacific Coast flour well adapted to the production of cookies such as drop cakes, shortbreads, etc.

Collaborator	H_2O	Ash	N×5.7	Maximum viscosity	Loaves without bromate					Loaves with 1 mg. bromate				
					Loaf volume	Oven spring	Break	Crust color	Grain	Loaf volume	Oven spring	Break	Crust color	Grain
	%	%	%	° *MacM.*	*Cc.*					*Cc.*				
R. M. Bohn	9.8	0.44	7.4	28	406	Medium	Very torn	Pale	Close; elongated	416	Medium	Very torn	Pale	Close; elongated
C. O. Oppen	8.8	0.44	7.6	32	440	Medium	Ragged	Dark	Coarse	442	Medium	Ragged	Dark	Coarse
Geo. Garnatz	8.9	0.45	7.5	33	373	Medium	Very ragged	Pale	Round coarse	378	Medium	Torn	Dark	More coarse
Pearl Brown	9.9	0.44	7.3	—	470	Medium	Ragged	Dark	Coarse; elongated	445	Medium	Torn	Dark	Very coarse
E. L. Ulrey	9.5	0.43	7.1	37										
J. A. Dunn	9.9	0.39	7.5	37	450	Medium	Torn	Pale	Coarse	430	Small	Ragged	Pale	Very coarse
Averages	9.5	0.42	7.4	33	428									

Remarks of collaborators: R. M. Bohn—Good cooky flour. C. O. Oppen—For products requiring very weak flour; high in diastase; Pacific coast flour. Geo. Garnatz—A very satisfactory type cooky flour; should give excellent results in products such as drop cakes, fig bars, and shortbreads. J. A. Dunn—Applicable to light goods such as vanilla wafers, shortbreads, etc.

TABLE II

Baking and Viscosity Tests on Flour B–1

A Michigan flour, ordinarily best suited for topping purposes (cracker doughs) and for general application in the production of hard sweet doughs

Collaborator	H_2O	Ash	N×5.7	Maximum viscosity	Loaves without bromate					Loaves with 1 mg. bromate				
					Loaf volume	Oven spring	Break	Crust color	Grain	Loaf volume	Oven spring	Break	Crust color	Grain
	%	%	%	° *MacM.*	*Cc.*					*Cc.*				
R. M. Bohn	9.3	0.41	9.2	38	392	Small	None	Pale	Very close	421	Medium	Very ragged	Pale	Very close; elongated
C. O. Oppen	9.3	0.41	9.3	46	420	Small	None	Pale	Close	425	Small	Slight	Pale	Close
Geo. Garnatz	8.6	0.42	9.3	50	400	Large	Slightly ragged	Pale	Coarse; round	402	Large	Slightly ragged	Dark	Coarse; round
Pearl Brown	9.4	0.41	9.1	—	430	Small	Slightly rough	Medium	Fine; elongated	410	Small	Very little	Medium	Slightly coarse
E. L. Ulrey	9.1	0.40	9.0	51										
J. A. Dunn	9.4	0.38	9.2	50	415	Small	Torn	Pale	Coarse	430	Medium	Torn	Pale	Close
Averages	9.2	0.41	9.2	47										

Remarks of collaborators: R. M. Bohn—Good cracker dough and cooky flour. C. O. Oppen—Good cracker dough flour; tests place next to A–2 for weakness. Geo. Garnatz—About right for cracker doughs and general use in usual hard sweet goods. J. A. Dunn—Applicable for general cooky work and possibly for doughing up with a strong cracker sponge.

TABLE III

Baking and Viscosity Tests on Flour F-3

An Indiana flour, strong to such a degree that our shops have noted differences when it has been applied to our set-up, and if it can be used at all for sponging purposes, compensation for its greater strength would have to be made.

Collaborator	H_2O	Ash	N×5.7	Maximum viscosity	Loaves without bromate					Loaves with 1 mg. bromate				
					Loaf volume	Oven spring	Break	Crust color	Grain	Loaf volume	Oven spring	Break	Crust color	Grain
	%	%	%	° *MacM.*	*Cc.*					*Cc.*				
R. M. Bohn	9.4	0.40	10.4	94	443	Large	Torn	Medium	Close; elongated	448	Large	Torn	Medium	Close; elongated
C. O. Oppen	9.0	0.41	10.9	129	465	Medium	Slight shell	Medium	Close; elongated	475	Medium	Shell	Medium	Close; elongated
Geo. Garnatz	8.7	0.41	10.9	120	415	Medium	Ragged	Medium	Close; elongated	390	Medium	Very ragged	Medium	Slightly round
Pearl Brown	9.6	0.40	10.7	—	440	Small	Smooth	Golden brown	Close; elongated	440	Small	Slightly rough	Golden brown	Close; elongated
E. L. Ulrey	9.5	0.40	10.3	125										
J. A. Dunn	9.2	0.38	10.7	117	440	Medium	Torn	Pale	Close	450	Medium	Ragged	Pale	Close
Averages	9.2	0.40	10.65	117	441									

Remarks of collaborators: R. M. Bohn—Very strong sponge flour; requires vigorous fermentation and should be used with a weak dough flour. C. O. Oppen—Too rugged to be desirable for cracker sponge use. Geo. Garnatz—An undesirably strong sponge flour. J. A. Dunn—A strong cracker sponge flour Should not be used straight, but should be blended with flour of lower strength.

TABLE IV

BAKING AND VISCOSITY TESTS ON FLOUR H–5

Milled from Ohio wheat. Ordinarily classified as cracker dough and hard sweet use, but in this instance is a border-line case which we have been classifying primarily for sponge purposes.

Collaborator	H_2O	Ash	N×5.7	Maximum viscosity	Loaves without bromate					Loaves with 1 mg. bromate				
					Loaf volume	Oven spring	Break	Crust color	Grain	Loaf volume	Oven spring	Break	Crust color	Grain
	%	%	%	° *MacM.*	*Cc.*					*Cc.*				
R. M. Bohn	9.0	0.42	10.2	52	396	Little	Very little	Pale to medium	Close; round	409	Little	Very little	Pale to medium	Close; elongated
C. O. Oppen	10.6	0.42	10.6	52	440	Good	Slight shell	Light	Slightly coarse; round	445	Good	Slight shell	Light	Slightly coarse; round
Geo. Garnatz	8.7	0.42	10.6	57	400	Small	Ragged	Pale	Round	395	Medium	Very ragged	Medium	Round
Pearl Brown	9.2	0.41	10.6	—	455	Small	Smooth	Light	Very fine; elongated	430	Small	Torn	Light	Fine; elongated
E. L. Ulrey	9.4	0.42	9.7	60										
J. A. Dunn	9.6	0.40	10.8	60	420	Small	Torn	Pale	Close; round	435	Small	Ragged	Pale	Coarse
Averages	9.4	0.415	10.4	56	422									

Remarks of collaborators: R. M. Bohn—Weak sponge and good cracker dough flour. C. O. Oppen—Very good cracker sponge flour; better for cracker dough use than K–4. Geo. Garnatz—Primarily a cracker sponge flour but gives indications that should be satisfactory in cracker doughs and hard sweets. J. A. Dunn—Should make a good cracker sponge flour.

TABLE V

BAKING AND VISCOSITY TESTS ON FLOUR K–4

Milled from Indiana wheat. Rather heavily treated and has been found to work out very nicely for sponge work

Collaborator	H_2O	Ash	N×5.7	Maximum viscosity	Loaves without bromate					Loaves with 1 mg. bromate				
					Loaf volume	Oven spring	Break	Crust color	Grain	Loaf volume	Oven spring	Break	Crust color	Grain
	%	%	%	° *MacM.*	*Cc.*					*Cc.*				
R. M. Bohn	9.4	0.45	9.2	55	409	Medium	Very torn	Pale	Close; elongated	424	Medium	Very torn	Pale	Close; elongated
C. O. Oppen	8.9	0.44	9.4	60	450	Good	Ragged	Light	Close; elongated	455	Good	Ragged	Pale	Close; elongated
Geo. Garnatz	9.2	0.45	9.3	71	390	Small	Little	Very pale	Slightly coarse; round	390	None	None	Very pale	Round
Pearl Brown	9.8	0.44	9.2	—	425	Small	Smooth	Dull	Close; elongated	405	None	—	Dull	Close; elongated
E. L. Ulrey	9.7	0.45	8.9	75										
J. A. Dunn	10.0	0.43	9.4	68	450	Medium	Ragged	Pale	Close	440	Medium	Ragged	Pale	Close
Averages	9.5	0.445	9.2	66	425									

Remarks of collaborators: R. M. Bohn—Fairly weak sponge flour; also well suited for cracker doughs. C. O. Oppen—Good cracker sponge flour; baking results show greater strength over H–5 than is indicated by viscosity. Geo. Garnatz—A desirable cracker sponge flour. J. A. Dunn—Applicable for cracker doughs and cookies requiring a stronger flour.

The descriptions of the flours given at the head of each table were supplied by Mr. Garnatz as a result of his wide laboratory and bakeshop experience with the various flours. As mentioned, the remarks by the committee members were made without this knowledge. Mr. Garnatz' assistants, who did the work in his laboratory and interpreted the results, did not know the identity of the flours until after they reported their results, so the results from his laboratory are on a par with those of the other committee members.

Discussion

Analytical results. The checks were not better than fair, even when calculated to a uniform moisture content. In the tables they are shown as received.

Viscosity. The checks were fair only, although the variations were rather consistent from one laboratory to another. An examination of the viscosity results compared to the commercial utility of the flours shows that viscosity bears a definite relation to strength as determined by shop practice. This was equally true of the five flours tested last year. In fact, from the results so far reported during the two years' work, we can set up tentative viscosity standards for the three types of biscuit and cracker flours of standard patent grade. These tentative standards (by the method given) for standard patent soft wheat flours are:

Cracker sponge	50 to 80 degrees	MacMichael
Cracker dough (and some sweet goods)	40 to 60 "	"
Sweet goods	20 to 40 "	"

So far no grades other than standard patent have been considered, and the relation of viscosity to type, as determined by commercial use in cracker plants, of good clears and patents should be studied.

Baking test results. As before, and as generally found in collaborative baking test work, the comparative test loaves (by description and volume, at least) were atrociously dissimilar. Nevertheless the collaborators were able to interpret their own progeny so that in connection with viscosity, they accurately classified the flours.

General Remarks and Recommendations

The work of the last two years has shown such consistently good results for viscosity as an indication of flour strength for standard patents, that tentative viscosity standards are suggested. On the other hand, the baking test seems of less collaborative value. The competent and experienced chemist can accurately judge biscuit and cracker flours by a baking test, but the loaves from the same flour in different labora-

tories show poor resemblance to each other. This situation appears rather discouraging in the opinion of three members of the committee. Mr. Garnatz feels that the baking test is not nearly as hopeless as the remarks just made would indicate. Indeed, if viscosity does not work out equally well for grades other than standard patent, resort to the baking test may be a necessity.

It is suggested that the work be continued another year with some attention paid to clears and patents which have been found useful in biscuit and cracker work, using both viscosity and the baking test as a measure of utility.

Another point for consideration, suggested by this year's wheat crop, is the comparative value of flours of the same strength as determined by viscosity but widely different in protein, and vice versa. For instance, flours of the following characteristics were common with this crop:

No.	% Ash	% Protein	Viscosity	Probable Type
1	0.40	9.5	35	cooky
2	0.40	7.0	35	"
3	0.40	10.0	60	sponge
4	0.40	8.0	60	"

Roughly, flours No. 1 and No. 2 are of the same strength. Flour No. 1 theoretically contains much gluten of poor quality, while flour No. 2 contains little gluten of excellent quality. Similarly, flour No. 3 has much gluten of poor quality, while flour No. 4 has little gluten of excellent quality. Preliminary observations by the chairman of your committee indicate that flour No. 2 is a flour far superior to flour No. 1, and flour No. 4 is much better than flour No. 3. In other words, it seems to be preferable to get the desired strength in a flour with as little gluten of high quality as possible. This is a most interesting point and should be investigated.

Still another question is the effect of bleaching. Heavy Agene and Chlorine bleaches weaken flours, as is well-known, without lessening the viscosity. This may lessen the value of the viscosity as a measure of classifying biscuit and cracker flours, and should receive consideration in future work.

The points mentioned cannot all be covered in next year's work, but they should be covered before it will be possible to bring this problem to a successful conclusion.

REPORT OF THE COMMITTEE ON TESTING RYE FLOUR

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(Read at the Annual Meeting, June 1935)

The work of the committee has been greatly handicapped by the fact that we have not been able to have a committee meeting during the last two years. Even at last year's convention, only two members of the committee were present. Therefore, correspondence has had to be depended upon.

The first work undertaken this year was an attempt to increase the diagnostic value of the method reported on last year, that is, to render it a greater help in differentiating baking values of various rye flours. To this end the formula was modified by decreasing the yeast from 2½ to 2% and increasing the salt from 1½ to 2%. The mixing time in the Hobart-Swanson mixer was decreased from 3 to 2 minutes. The fermentation time was increased by one-half hour by adding 15 minutes to the periods for first and second punches. The proof period was increased from 45 minutes to one hour and then duplicate loaves were to be made and proofed for two hours instead of one hour. And the proportion of dark rye to clear flour was changed from 1 to 4, as used last year, to 1 to 3.

The changes in the formula were made with the idea of producing better loaves. The mixing time was reduced to secure a better and more easily handled dough. The proofing time was greatly increased with the idea of showing differences in stability and the proportion of dark rye was increased to minimize the influence of the clear flour on the finished loaf.

The different members of the committee were requested to use their own materials and report their findings as the result of making these various changes.

The consensus of opinion of the committee is that the change in mixing time, and the changes in formula are improvements but that the long proof periods are unsatisfactory.

Much work has been done to determine the character of bread made from wheat flour of different varieties of wheat and grown in different localities. But we do not have similar experiments on rye flours. For

this reason the chairman of the committee desired to secure samples of rye flour that were produced in widely different sections that would have different characteristics due to the influence of variety, climate, and milling conditions.

COLLABORATIVE BAKING RESULTS

Collaborator A

Sample	Grade	Weight	Volume	General appearance	Crust color	Crumb color	Grain	Texture	Odor and taste	Remarks
Perfect score	—	—	—	25	10	10	15	15	25	
1123	White	—	775	21	7	9	12	14	25	
1125	"	—	825	22	8	9	12	14	25	
1121	Medium	—	700	16	7	8y	14	14	24	Y = Yellow
1122	"	—	660	18	8	9	14	14	25	
1124	Meal	—	590	17	8	10	13	14	25	
1126	"	—	560	21	6	10	15	14	25	Dough too stiff

Collaborator B

1123	White	271	782	25	10	10	15	15	25	Very good
1125	"	271	810	25	10	10	15	15	25	Very good
1121	Medium	271	692	18	10	8dy	15	15	25	Over-proofed dy = dark yellow
1122	"	270	660	18	10	10dg	15	15	25	Over-proofed dg = dark grey
1124	Meal	271	558	13vf	10	10dr	15	15	25	Very much over-proofed vf = very flat dr = dark red
1126	"	271	603	20	8 l	10dr	15	15	24	Slightly over-proofed dr = dark red l = light

Collaborator C

1123	White	130	365	15	9	9.0	13	12	24	Over-proofed
1125	"	132	305	20	10	10.0	14	12	25	"
1121	Medium	133	360	20	10	10.0	14	14	25	
1122	"	132	335	15	9	9.0	13	13	24	Rough crust
1124	Meal	135	265	20	9	9.0	13	12	24	" "
1126	"	124	250	15	8	10.0	14	13	25	Pale bloom

Collaborator D

1123	White	—	945	24	9.0	7.5	14.0	13.5	24.0
1125	"	—	992	25	9.0	10.0	14.5	14.5	24.0
1121	Medium	—	728	22	9.5	8.0	12.5	13.5	24.0
1122	"	—	837	24	9.5	9.0	14.0	14.0	23.5
1124	Meal	—	635	24	9.0	9.0	14.0	14.0	23.5
1126	"	—	550	23	9.5	8.5	13.0	13.5	24.0

Collaborator E

1123	White	272	937	22	7	8.0	13	14	25
1125	"	272	974	21	9	7.5	14	12	25
1121	Medium	282	932	20	8	9.0	14	14	25
1122	"	286	891	22	9	8.0	14	13	25
1124	Meal	290	768	21	8	8.0	13	14	25
1126	"	294	788	22	7	9.0	14	14	25

In order to secure these samples, letters were sent to 25 mills located in the principal states that produce rye. And to insure getting locally grown rye, the letters were sent to mills having small milling capacity. Of the 25 letters sent out inquiring if the selected mills could furnish the flour desired, 17 of them made no reply. A few others could not furnish the flour on account of the drought or some other reason. As a result only 6 samples were secured. Two of them were white rye flour, two of them medium rye, and two were rye meals. These samples were divided and sent to the committee members, who were requested to bake them according to the modified formula further changed by using equal parts of rye and clear flour with all the grades of rye submitted and proofing all doughs for one hour. A summary of the baking results submitted by five of the six members of the committee is given in the table.

It was intended that all the collaborators should use doughs made from 200 g. of the flour mixture, but through a misunderstanding this was not done in all cases. Also one or more of the collaborators did not have access to a Hobart-Swanson mixer.

An examination of the table shows that there was not a good agreement among the collaborators as to which rye in each of the grades gave the best loaf.

Whether this failure to agree as to the best sample of rye of each grade studied was due to lack of experience with the method, or different interpretation of the baking results as expressed on the score cards, or whether the samples were too nearly alike to be definitely differentiated, has not been determined.

Recommendations

It is recommended:

That the work be continued.

That the next committee study a greater number of samples of the same grade of rye.

That ash be determined on the rye flours.

That the relation of ash contents of rye flour to the color, odor and taste of the rye bread be studied.

That consideration be given as to proofing periods most suitable for the different grades of rye.

That the values for the different items in the score card be given further consideration.

SOME OBSERVATIONS ON THE DIFFERENTIATION OF CAKE AND PASTRY FLOURS BY THE VISCOSITY OF THEIR WATER SUSPENSIONS

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(Received for publication February 23, 1935)

Recently this laboratory had occasion to examine a series of flours sold in Canada as cake and pastry flours. Opportunity was taken to compare these flours by the viscosity of their water suspensions. Believing that the observations may be of some value, the data are herewith given. The data of a number of patent flours milled by several mills in different parts of Canada from hard red spring wheat are also given for comparison.

The viscosity determinations were made with a Wallace & Tiernan viscosimeter. The flour was weighed into a flask, shaken with 100 cc. of distilled water and left to stand for 30 minutes at 80° F. At the end of this time 2 drops of capryl alcohol were added and the suspension, after shaking, was poured into the viscosimeter cup. The readings were taken after adding 1 cc. increments of $N/1$ lactic acid. To save space only the final readings are given in Table I. Figures 1 and 2 were drawn from the complete data. In Figure 1 the curves for suspensions containing 15 g. of flour in 100 cc. of water are given. There is considerable range in the viscosity values of the whole series. The pastry flours are grouped within a narrow band near the bottom of the figure, the hard wheat flours in a wider band near the top, with the winter wheat flour occupying an intermediate position. As there is considerable range in the protein content of these flours these values would be influenced by the amount of protein in the samples. Rich [1] and Bayfield [2] have shown that this factor can be eliminated by weighing samples containing equal amounts of protein for the viscosity test. Figure 2 illustrates the data obtained from samples weighed to contain a constant quantity (2 grams) of protein. The range for the whole series is considerably narrowed. Rich [1] in a study of the viscosity of hard spring wheats found only a small variation among 150 flours of widely differing "strengths." The hard spring wheat flours of this

[1] Rich, C. E. The relationship between viscosity, total protein content, ash content and baking strength of flours from Western Canadian hard red spring wheat. Cereal Chem. 9: 535–559 (1932).
[2] Bayfield, E. G. The viscosity test. Cereal Chem. 11: 637–647.

TABLE I

ANALYSIS OF A NUMBER OF CAKE AND BREAD FLOURS

Flour No.	Origin	Ash content	Protein content	Viscosity (W. & T.)	
				15 g. flour	2 g. protein
		%	%	*Degrees*	*Degrees*
	Soft Wheat Flours Sold for Cake Making				
1	Ontario soft wheat	0.36	8.50	12	34
2	Canadian soft wheat	.45	9.00	12	28
3	Canadian soft wheat	.43	8.80	13	33
4	Ontario soft wheat	.49	9.30	14	29
5	Canadian soft wheat	.38	8.50	15	36
6	Pacific Coast wheat	.42	9.00	15	43
7	Made in England	.37	8.30	17	45
8	Made in England	.38	8.20	20	47
9	Australian wheat	.37	8.10	21	65
10	Alberta winter and Pacific Coast wheats	.40	9.30	24	44
11	Australian wheat	.35	8.30	31	85
12	Alberta winter and Pacific Coast wheats	.57	10.80	36	48
13	Alberta winter wheat experimentally milled	.42	11.20	66	66
	Hard Spring Wheat Flours Sold for Bread Making				
14	Canadian wheat	0.40	11.80	90	86
15	" "	.36	11.50	95	87
16	" "	.38	11.50	99	90
17	" "	.37	12.00	104	90
18	" "	.36	11.70	105	90
19	" "	.39	12.00	105	83
20	" "	.42	13.50	121	85
21	" "	.38	13.50	130	88
22	" "	.42	16.00	162	90

series grouped themselves closely together with a range of only 7° (W. & T.) indicating only slight differences in the hydration capacities of their proteins.

The values for the pastry flours were still much below those for the hard spring wheats indicating that their proteins have a lower hydration capacity. There was a much wider differentiation in this series, the values ranging from 28° to 85°. The values for the Australian flours (Nos. 9 and 11) were comparatively high, and were in the spring wheat class. Flour No. 11 had almost exactly the same ash and protein contents as flour No. 1 yet their viscosity values were 85 and 34, respectively. The values would indicate that flour No. 11 was as poor as the spring wheat flours for pastry making and that flour No. 9 was similar to the winter wheat flour (No. 14). Baking tests indicated that both of these flours were similar to the other pastry flours of the series.

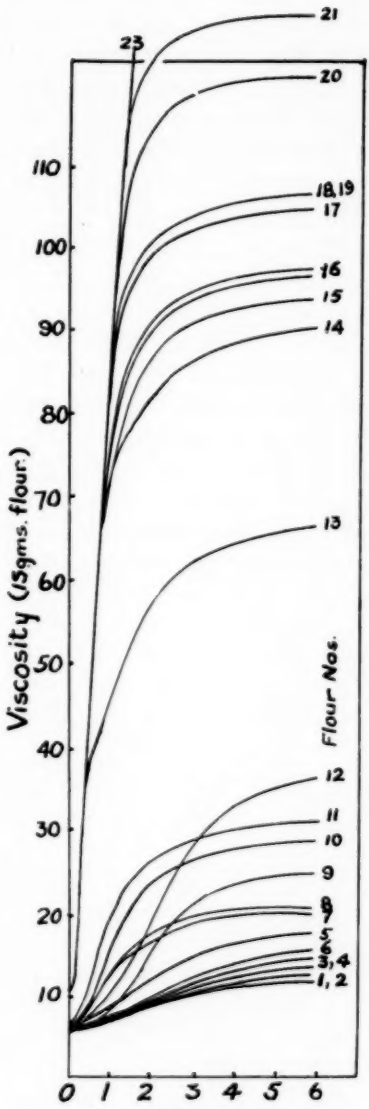

FIG. 1

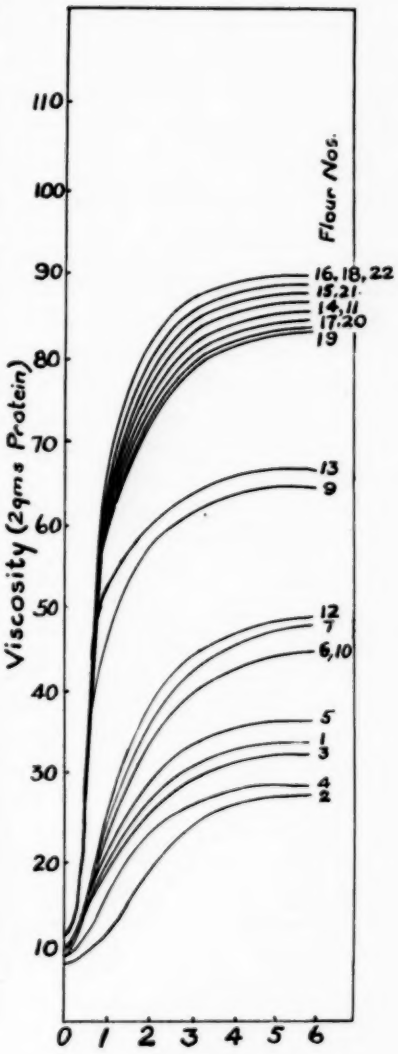

FIG. 2

Fig. 1. The viscosity of water suspensions of wheat flours based on samples containing 15 grams of flour.

Fig. 2. The viscosity of water suspensions of wheat flours based on samples weighed to contain 2 grams of protein.

The viscosity curves were all similar in shape with the exception of that for flour No. 12 which was a high ash flour and whose curve was depressed due to buffer action. Part of the range in viscosity values is no doubt due to variation in ash content, particularly for the pastry flour series. There is a tendency for the values to diminish with ash content although there are several important exceptions indicating that the flours actually differed in the inherent hydration capacity.

No conclusions could be drawn from this short series as to the significance of the values of either method of viscosity determination with respect to the value of the flours to the cake baker. The viscosity method based on samples weighed to contain equal quantities of protein would seem to be preferable to the method based on equal amounts of flour, for several reasons: the influence of the amount of protein in the flour is eliminated; there is a greater differentiation between flours; and the viscosity values are of a higher order. In the latter method the values are so close to zero for the lowest protein flours that differentiation between flours is difficult. The order in which the flours are placed by the two methods is different. Which order is correct can only be determined by a complete examination of a known series of flours.